Evaluation of the 2013 Predictions of Run-Timing and Survival of Wild Migrant Yearling Chinook and Steelhead on the Columbia and Snake Rivers

Technical Report

Postseason Analysis
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Executive Summary

Columbia Basin Research uses the COMPASS model on a daily basis during the outmigration of Snake River Chinook and steelhead smolts to predict downstream passage and survival. Fish arrival predictions and observations from program RealTime along with predicted and observed environmental conditions are used to make in-season predictions of arrival and survival to various dams in the Columbia and Snake rivers. For 2010, calibrations of travel and survival parameters for two stocks of fish—Snake River yearling PIT-tagged wild Chinook salmon (chin1pit) and Snake River PIT-tagged steelhead (lgrStlhd)—were used to model travel and survival of steelhead and Chinook stocks from Lower Granite Dam (LWG) or McNary Dam (MCN) to Bonneville Dam (BON). This report summarizes the success of the COMPASS/RealTime process to model these migrations as they occur.

We compared model results on timing and survival to data from two sources: stock specific counts at dams and end-of-season control survival estimates (Jim Faulkner, NOAA, pers. comm. January 8, 2014). The difference between the predicted and observed day of median passage and the Mean Absolute Deviation (MAD) between predicted and observed arrival cumulative distributions are measures of timing accuracy. MAD is essentially the average percentage error over the season. The difference between the predicted (model) and observed (control-release data) survivals is a measure of survival accuracy. MAD values at BON were: 8.32% for Chinook (chin1pit) and 7.14% for steelhead (lgrStlhd).

This year for Chinook, the model and the survival data are in agreement. Point estimates of the modeled survivals through the entire Snake Columbia system (LWG-BON) is 0.56 for Chinook and 0.35 for steelhead. A point estimate of control-release survivals is 0.70 for Chinook and 0.59 for steelhead, although the number of wild steelhead in the lower river very low.

As in previous years, there are problems in reconciling the three types of measures on the river: COMPASS model output, the control-release study data and the observations of PIT-tagged fish at the dams. Survivals have been very consistent between years as predicted by COMPASS.

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Introduction

During the 1996 migration season, Columbia Basin Research launched a prototype, run-timing system, named CRiSP/RealTime for its two principal components. Program RealTime was developed to take advantage of historical data to predict the proportion of a particular population that had arrived at an index site in real-time and to forecast the elapsed time to some future percentile in a migration at the site. The CRiSP program (Columbia River Salmon Passage model) predicted downstream migration and survival of individual stocks of wild and hatchery spawned juvenile fish from the tributaries and dams of the Columbia and Snake rivers to the estuary. The model described in detail fish movement, survival, and the effects of various river operations on these factors. Beginning in 2007, the downstream modeling program CRiSP was replaced with COMPASS; a regionally accepted data set and model of juvenile passage and survival developed by collaborators at CBR, NOAA/NMFS, BPA and other regional agencies and tribes.

The CRiSP/RealTime project was originally launched in an effort to provide real-time in-season projections of juvenile salmon migration to managers of the Columbia-Snake River hydrosystem to assist the managers in decisions about mitigation efforts such as flow augmentation, spill scheduling and fish transportation. In COMPASS, fish migration and survival is a function of river conditions, dam configurations and reservoir operations which are modeled from flow and spill forecasts, historical data, and year-to-date data.

At the beginning of 2007, two stocks had available travel-time and survival calibrations for use in the new COMPASS model: steelhead and yearling Chinook of both wild and hatchery origin from Lower Granite Dam to McNary Dam and then from McNary Dam to Bonneville Dam. Although the RealTime portion of the model continued to generate predictions for numerous Chinook stocks, their movements below Lower Granite Dam were modeled with common migration and survival parameters. Since 2008, an acceptable calibration of Chinook and steelhead using only data of wild fish was available.

This report is the postseason analysis of the utility and accuracy of the COMPASS portion of the 2013 predictions of survival and passage that uses available calibrations along with in-season river conditions (flow, spill, TDG and temperature) that are initially predicted (in early season) and eventually observed. The effectiveness of these modeling efforts are compared to observations of passage and survival that are now available since the season is complete. The analyses and graphic presentations herein document the year’s passage of select stocks of juvenile salmon and steelhead and demonstrate changes in accuracy of the model predictions as the season progressed.

Methods

The COMPASS and RealTime models have their own calibrations and documentation separate from this postseason analysis of their joint performance. COMPASS is described in more detail in Zabel et al. (2008). See also: http://www.springerlink.com/content/hu614372k277/?sortorder=asc&p_o=20 . For further details on the RealTime forecaster, see http://www.cbr.washington.edu/rt/rt.html.

In 2007, the COMPASS model had two calibrations complete for Columbia/Snake River hydrosystem: Yearling Chinook and steelhead from the Snake River between Lower Granite Dam and Bonneville Dam, but these included both hatchery and wild fish. Since 2008, calibrations were available for wild fish only of both species. These are coded “chin1pit” and “lgrStlhd”. Other stocks were also modeled with these calibrations even though the specific parameters were not calibrated separately for the individual stocks.

COMPASS predictions are made daily and are a function of 1) expected and/or known distribution of fish, 2) calibrated migration and survival parameters, and 3) expected and/or known environmental conditions. The output of a daily run includes details on fish passage for the entire year and therefore is predictive. The predictions are then compared with observations at the end of the year. Observations are counts of individually identified PIT-tagged fish that belong to one of six groups: the calibrated stocks: “chin1pit”, “lgrStlhd”, and additional groupings including: “real”, a select group of Chinook from Snake River watersheds; “mcnChin1S”, Snake River Spring/Summer Chinook ESU passing MCN; “mcnStlhdC”, Upper Columbia River Steelhead ESU passing MCN; and “mcnStlhdS”, Snake River ESU Steelhead passing MCN. The groups of fish, their RealTime name and applicable calibration are identified in Table 1.

Table 1 Observation/Prediction matrix and travel-time and survival calibrations for COMPASS predictions (see www.cbr.washington.edu/crisprt).

Sp[1].	Field Name	RealTime Name	Release Site	COMPASS Sites	Calibr’n
Y	PIT-tagged Wild Run-At-Large	chin1pit*	LWG	LGS to BON	Chin1
S	Snake River Wild Migrant	lgrStlhd*	LWG	LGS to BON	Stlhd
Y	Snake River ESU Spring/Summer	mcnChin1S	MCN	JDA to BON	Chin1
S	Snake River ESU	mcnStlhdS	MCN	JDA to BON	Stlhd
S	Upper Columbia River ESU	mcnStlhdC	MCN	JDA to BON	Stlhd

[1] Species: (Y= Yearling Chinook; S=Steelhead)
* NOAA/NMFS calibrated stock.

Summaries

Numerous summaries can be derived from the detailed COMPASS outputs that include fish routing and environmental conditions on a day-by-day and dam-by-dam basis, but encompassing measures such as overall passage and survival are the most revealing of the larger processes at work. Predicted and observed median passage day and arrival distributions as well as survival of stocks at various locations are compared. Observations that are available for comparison to model output are limited to detections of PIT-tagged fish in the bypass system. The real-time efficiency of the dam in routing these fish into the bypass system is unknown and therefore the observation is an index of passage only. Bypass efficiency (BE) varies in time at a dam and between dams.

The formula expressing BE considers these independent diversions and accounts for the fact that fish may be attracted to spill flow in preference to turbine flow. A formula for BE during a time step is:

$$BE = FGE \cdot (1 - SLE) \cdot (1 - F \cdot SE) \cdot 100 \tag{1}$$

- F = fraction of daily flow that passes in spill.
- SE = Spill Efficiency, the fraction of fish that pass in spill relative to the fraction of flow passing in spill. This is often > 1.

– *SLE* = Sluiceway Efficiency or Surface Bypass Collector Efficiency, in COMPASS, these are equivalent.

– *FGE* = Fish Guidance Efficiency, the fraction of fish passing into turbine intake that are bypassed.

BE is also equal to the ratio of counts at the blue dot to the count at the red dot (Figure 1). The counts at the blue dot position are the available observations. Improvements to the index using estimates of FGE, SLE, and SE are possible, and required for getting the actual count of arrivals correct. This is an integral part of the RealTime process for assessing the number of fish and their distribution at the first dam (LWG or MCN depending on the stock).

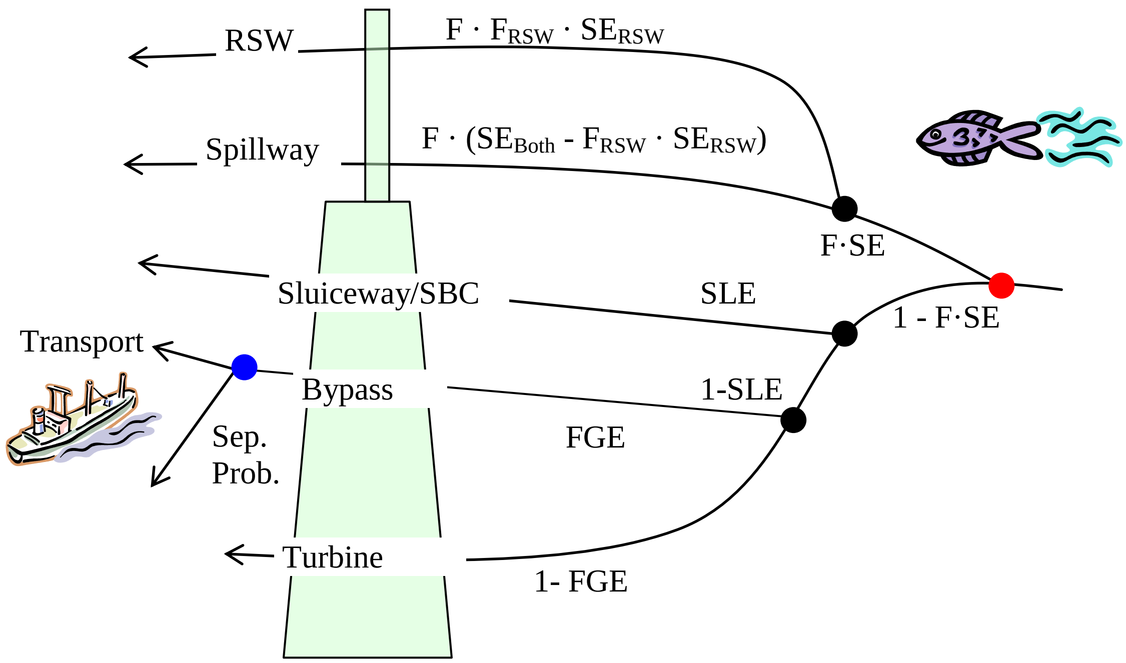


Figure 1 Possible routings of fish at a dam. The dots represent bifurcations of the population where there are only two possible routes. In the case of the RSW and Spillway routes, these do NOT necessarily sum to one. F = fraction of daily flow that passes in spill. SE_{Both} = Spill Efficiency for both normal spillway and RSW, the fraction of fish that pass in spill relative to the fraction of flow passing in spill. This is often > 1. SLE = Sluiceway Efficiency or Surface Bypass Collector Efficiency, in COMPASS, these are equivalent. FGE = Fish Guidance Efficiency, the fraction of fish passing into turbine intake that are routed to the bypass system.

MAD

Travel prediction accuracy is measured in two ways: 1) with the difference between the day of a predicted percentile and its observed day (at the end of the season) or 2) with mean absolute deviation (MAD) between cumulative arrival percentages and corresponding predictions over the entire season. When the season ends, the cumulative percent passage of each stock, on each day, at each site are known. For every day during the season that a prediction was made, the absolute difference between the predicted and observed cumulative passage is computed and these are summed over all prediction days:

$$MAD = \frac{1}{N}\sum_{i}^{N}\left|F_i - \hat{F}_i\right| \times 100 \qquad (2)$$

where F_i = cumulative passage percentage on day *i* computed from observations, $\hat{F}_i$ = predicted cumulative passage percentage *for day* i *made on day* i. This is a single indicator of the average discrepancy between the model and the data. However, the results are easy to skew downward by including more of the tails of the cumulative distributions because prior to (or after) the run it is easy to predict and observe that the run is at 0% (100%) which adds another zero to the sum in eq(2). We compute MAD when both the predicted and observed passage is between 0.5 and 99.5 percentiles. We found that summing over the 0 – 100 percentiles of the observations was not revealing due to extraneous outliers in stocks with very low numbers which in turn drops the MAD values to artificially low values because the peak of the run is a small part of the time period. MAD is also used to assess the utility of the calibration in modeling similar stocks.

A "snapshot" measure called the OneDay-MAD evaluates any COMPASS run against the final observed fish passage:

$$OneDayMAD = \frac{1}{N}\sum_{i}^{N}\left|F_i - \hat{F}_{ij}\right| \times 100 \qquad (3)$$

where $\hat{F}_{ij}$ = predicted cumulative passage percentage *for day* i *made on any day* j. There are three OneDayMAD computations of interest: "Post-MAD" for a COMPASS run when environmental conditions and LWG arrival distribution is known; "First-MAD" which evaluates an early run when both environmental and arrival are predicted; and "Pre-Post-MAD" which evaluates a special COMPASS run that uses the predicted environmental conditions with the final (known) arrival observations.

Fish Guidance Efficiency and Spill conditions during fish passage are also collected since they could affect interpretation of passage numbers. Spill, flow and other river conditions data is available from DART (http://www.cbr.washington.edu/dart/river.html). FGE is not directly measured but is computed as a function of environmental conditions and also was extracted from COMPASS input and output files for a seasonal, stock-specific average.

Survival

The chin1pit and lgrStlhd stocks correspond to wild yearling Chinook and steelhead controls of Snake River origin fish released at either Lower Granite Dam or McNary Dam. For the control data, weekly releases were separately analyzed for their survival to downstream locations (Faulkner, NOAA, pers comm. January 8, 2014.) These data-control survivals are compared to the COMPASS- generated survival. They *are* different measures. Control-release survivals are for each cohort and vary across the season. A single measure of survival is taken to be the count-weighted average of the weekly cohort survival across the season. COMPASS generates a prediction of the aggregated survival for the entire season every day it is run and these values tend to converge and stabilize over the season such that changes in the predicted survival become smaller from day to day as the season progresses.

Reach by reach survival are compared where possible and overall survival to BON or MCN are compared to the COMPASS model outputs.

Results

The chin1pit and lgrStlhd COMPASS stocks were modeled on corresponding wild fish originating in the Snake River. The chin1pit calibration was also applied to the movement and survival of the "real" and "mcnChin1S" stocks in COMPASS. The lgrStlhd calibration was also applied to "mcnStlhdC" and “mcnStlhdS” stocks. The calibrated stocks “chin1pit” and “lgrStlhd” are the emphasis of the analysis and are identified in appropriate tables by shading.

Summaries

The counts of stocks observed at various locations are shown in Table 2. These are recorded counts in the bypass system, not necessarily the total number passing the dam. The declared median passage day which is the in-season day when COMPASS predicts “this day is the median passage day” is shown in Table 3. The observed day-of-year of median passage is shown in
Table 4.

Details of the cumulative passage distribution of the individual stocks are shown in “Appendix 1: Observed Cumulative Counts” and illustrate the lack of symmetry in arrival detections across the season (time) and along the river (space). It is not possible for there to be more fish at a lower dam compared to an upper dam. If survival is perfect, the counts would be the same. All other mechanisms produce an increase in mortality and therefore steadily dropping counts as the cohorts move downstream. Model results are difficult to evaluate in light of observation errors such as these. The arrivals of chin1pit and lgrStlhd were both bimodal and both stocks generated more observations at LGS than upstream or downstream.

Timing prediction accuracy: MAD

The MAD values depict the average daily error in predicted percentage for the season and are shown in Table 6 (an alternative in Table 7). When MAD is very low, there is good correspondence between the prediction and the observations. MAD values over the 0.5-99.5% percentile range for chin1pit and lgrStlhd at MCN were 7.1% and 6.8% respectively. At BON, 8.3% and 7.1% respectively.

Final Day MAD (Post-MAD) uses the hindsight of the true release distribution and known flows and spill as shown in Table 8. At MCN, MAD values over the 0.5-99.5% range for chin1pit and lgrStlhd were 9.2% and 10.0% respectively. At BON, 9.5% and 9.8% respectively. Pre-Post-MAD, uses the hindsight of the true release distribution, but uses pre-season predictions of flow and spill, and is shown in
Table 9. Pre-Post-MAD values over the 0.5-99.5% range for chin1pit and lgrStlhd at MCN were 8.6% and 9.2% respectively. At BON, 9.1% and 8.8% respectively.

Spill and Fish Guidance

Spill conditions and observed passage timing are illustrated in Figure 5. Fish have various routes through the dam (e.g. the spillway, surface collector, or turbine). Related to spill passage is the efficiency of the dam at routing non-spilled fish into the bypass system. Bypass fraction is based on fish guidance efficiency (FGE) and other measures. The ratio of all arriving fish that end up in the bypass system is the bypass fraction. Bypass fraction computed by COMPASS is shown in
Table 10. The bypassed fraction is always lower or equal to FGE (see Figure 1), and is sensitive to spill.

In a dam, the bypass system is where PIT-tagged fish are observed. Thus, high spill and low FGE both result in fewer observations. Depending on spill and the availability of other possible passage routes (Figure 1), the bypassed fraction may be a small fraction of the overall total (e.g. BON =0.11 for chin1pit, see
Table 10). Since only bypassed fish are counted as “observed” this is the most important explanation for seemingly paradoxical results, e.g. relatively high observations at a downstream dam compared to an upstream dam (Appendix 1: Observed Cumulative Counts), and certainly means that observations

in the bypass system alone can not be used for computing survival.

Survival

Modeled survival generally converges to a stable value as the season progresses as evidenced by the time series of the survival predictions (see Appendix 4: Survival Predictions with Data Controls). Time series of survival predictions made through the season are depicted in stages from LWG to MCN and MCN to BON. Final COMPASS-modeled survivals from LWG to BON in 2012 for chin1pit and lgrStlhd are 0.56 and 0.35 respectively. A summary of COMPASS generated survivals between dams is shown in Table 11 and Table 13 for the respective stocks (e.g. see http://www.cbr.washington.edu/inseason /smolt_snake_pit and choose "Survival Matrix").

COMPASS generated survivals can be compared in a limited way to control-data survival estimates (Table 12 and Table 14, respectively), but these are slightly different measures. Some of these model-data comparisons are shown in Figure 3. The controlled-release survivals were computed separately over the two sections of river and are further aggregated as the release-count weighted average of the cohort survivals. From LWG to MCN, COMPASS predicted survivals of 0.77 and 0.58 for chin1pit and lgrStlhd respectively. The corresponding data controls survivals were 0.83 and 0.66. Differences of -0.06 and 0.08 respectively. From MCN to BON, COMPASS predicted survivals of 0.73and 0.60 while the data controls survivals were 0.84 and 0.89 respectively. Differences of -0.11 and -0.29 respectively. Note that the confidence intervals for the control-release data are very large (Figure 19)

Results: Tables and Figures

Table 2 Counts of yearling stocks used in this analysis passing PIT-tag detectors at six prediction sites for 2013. These are a subset of all PIT-tagged fish passing the sites.

	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	8581	7754	3289	6447	2917	1818
lgrStlhd	6305	8194	4349	2403	1286	2137
mcnChin1S	NA	NA	NA	10470	5170	2847
mcnStlhdC	NA	NA	NA	550	357	419
mcnStlhdS	NA	NA	NA	2402	1286	2136

Table 3 Declared median passage day-of-year. This is the in-season day on which COMPASS identifies "this is the median arrival day". Note: Day 135 = May 15.

Stock	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	128	132	139	142	145	147
lgrStlhd	131	133	135	139	143	145
mcnChin1S	-	-	-	129	137	138
mcnStlhdC	-	-	-	128	132	135
mcnStlhdS	-	-	-	130	132	133

Table 4 Observed median passage day-of-year. Note: Day 135 = May 15.

Stock	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	131	130	132	129	134	137
lgrStlhd	132	132	134	133	136	138
mcnChin1S	-	-	-	129	134	137

mcnStlhdC	-	-	-	132	135	136
mcnStlhdS	-	-	-	133	136	138

Table 5 Difference between Declared and Observed median arrival day-of-year.
(i.e. Table 3 -

Table 4) Positive (negative) values mean the prediction was late (early).

Stock	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	-3	2	7	13	11	10
lgrStlhd	-1	1	1	6	7	7
mcnChin1S	-	-	-	0	3	1
mcnStlhdC	-	-	-	-4	-3	-1
mcnStlhdS	-	-	-	-3	-4	-5

Table 6 Mean Absolute Deviation (MAD) between predicted and observed passage distributions for selected sites and each stock using (0.5 -99.5%). They are computed over longer "tails" of the arrival distribution and are always less than MAD computed as in Table 7.

	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	6.54	8.03	7.75	7.06	8.83	8.32
lgrStlhd	2.45	1.83	5.63	6.78	7.24	7.14
mcnChin1S	-	-	-	2.21	4.05	3.25
mcnStlhdC	-	-	-	5.00	5.96	5.95
mcnStlhdS	-	-	-	6.55	5.30	7.92

Table 7 Alternative Mean Absolute Deviation (MAD) between predicted and observed passage distributions for selected sites and each stock using (1 -99%). They are computed over the shorter "tails" of the arrival distribution and are always greater than MAD computed as in Table 6 because it uses a more central portion of the run.

	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	7.06	8.85	8.48	7.68	9.76	9.00
lgrStlhd	2.67	1.90	5.92	7.27	8.18	7.55
mcnChin1S	-	-	-	1.14	3.25	3.55
mcnStlhdC	-	-	-	5.24	6.26	5.95
mcnStlhdS	-	-	-	7.03	6.09	8.40

Table 8 Final Day (Post) MAD. Allows for full knowledge of release distributions and best environmental information. Note that all Chinook stocks use the "chin1pit" calibration and all steelhead stocks use the "lgrStlhd" calibration.

	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	1.5	6.5	6.3	9.2	9.2	9.5
lgrStlhd	1.6	4.4	6.4	10.0	10.8	9.8
mcnChin1S	-	-	-	1.8	6.1	2.7
mcnStlhdC	-	-	-	2.6	2.9	5.2
mcnStlhdS	-	-	-	1.9	4.2	2.2

Table 9 Pre-Post-MAD. Compares year-end observations with a COMPASS run that used early-season's anticipated environmental information (April 11) combined with full knowledge of release distributions (observations).

Stock	LWG	LGS	LMN	MCN	JDA	BON
chin1pit 2013	1.7	5.6	5.4	8.6	8.3	9.1
lgrstlhd 2013	1.2	2.8	4.8	9.2	9.0	8.8
chin1pit 2012	1.7	3.4	7.2	1.7	8.5	4.1
lgrstlhd 2012	1.4	2.7	1.8	3.9	9.1	7.1
chin1pit 2011	6.0	2.9	2.3	8.2	2.5	9.1
lgrStlhd 2011	5.2	4.0	7.9	7.1	4.1	8.3
chin1pit 2010	1.3	3.5	13.1	1.6	5.4	15.2
lgrStlhd 2010	1.1	2.8	9.5	10.1	11.7	20.1

Table 10 Modeled bypass fraction in 2013. Fish released at LWG or MCN have theoretical bypass fractions = 1 because the observed counts are spill-adjusted prior to creating a release. Downstream, only fish entering the bypass system are enumerated and counted as observed. Previous year values are shown for comparison.

COMPASS effective Bypass Fraction	LGS	LMN	MCN	JDA	BON
chin1pit	0.26	0.19	0.30	0.21	0.11
lgrStlhd	0.30	0.29	0.12	0.12	0.08
mcnChin1S	-	-	0.83	0.21	0.11
mcnStlhdC	-	-	0.80	0.12	0.07
mcnStlhdS	-	-	0.80	0.12	0.08
2012 chin1pit	0.28	0.23	0.28	0.26	0.09
2012 lgrStlhd	0.33	0.33	0.11	0.15	0.06
2011 chin1pit	.25	.22	.27	.28	.09
2011 lgrStlhd	.27	.32	.10	.16	.06
2010 chin1pit	.25	.12	.33	.19	.11
2010 lgrStlhd	.24	.14	.15	.14	.07
2009 chin1pit	.31	.22	.36	.25	.11
2009 lgrStlhd	.37	.32	.15	.15	.08
2008 chin1pit	.24	.21	.31	.29	.09
2008 lgrStlhd	.24	.37	.18	.25	.06

Table 11 COMPASS generated survivals for chin1pit in 2013. Shaded cells indicate there is no corresponding data-based estimate of survival

	LGS	LMN	IHR	MCN	JDA	TDA	BON
LWG	0.91	0.86	0.83	0.77	0.66	0.59	0.56
LGS		0.95	0.92	0.85	0.73	0.65	0.62
LMN			0.97	0.89	0.77	0.69	0.65
IHR				0.93	0.80	0.71	0.68
MCN					0.86	0.77	0.73
JDA						0.89	0.85
TDA							0.95

Table 12 Weighted-average survival for control-release data on Snake River Wild Chinook in 2013 (Faulkner pers comm. March 13, 2014). Shaded cells indicate there is no estimation of the value.

	LGS	LMN	IHR	MCN	JDA	TDA	BON
LWG	0.91	0.86		0.83			
LGS		0.95					
LMN				0.97			
IHR							
MCN					1.04		0.84
JDA							0.81
TDA							

Table 13 COMPASS generated survivals for lgrStlhd in 2013. Shaded cells indicate there is *only* a COMPASS estimate of survival (no corresponding control-release data estimates of survival)

	LGS	LMN	IHR	MCN	JDA	TDA	BON
LWG	0.87	0.76	0.67	0.58	0.47	0.38	0.35
LGS		0.87	0.76	0.67	0.54	0.44	0.40
LMN			0.88	0.77	0.62	0.50	0.46
IHR				0.87	0.70	0.57	0.52
MCN					0.81	0.65	0.60
JDA						0.81	0.74
TDA							0.91

Table 14 Weighted-average survival for control-release data on Snake River Steelhead in 2013 (Faulkner pers comm. March 13, 2013). Shaded cells indicate no data.

	LGS	LMN	IHR	MCN	JDA	TDA	BON
LWG	0.94	0.92		0.66			
LGS		0.98					
LMN				0.72			
IHR							
MCN					0.84		0.89
JDA							1.10
TDA							

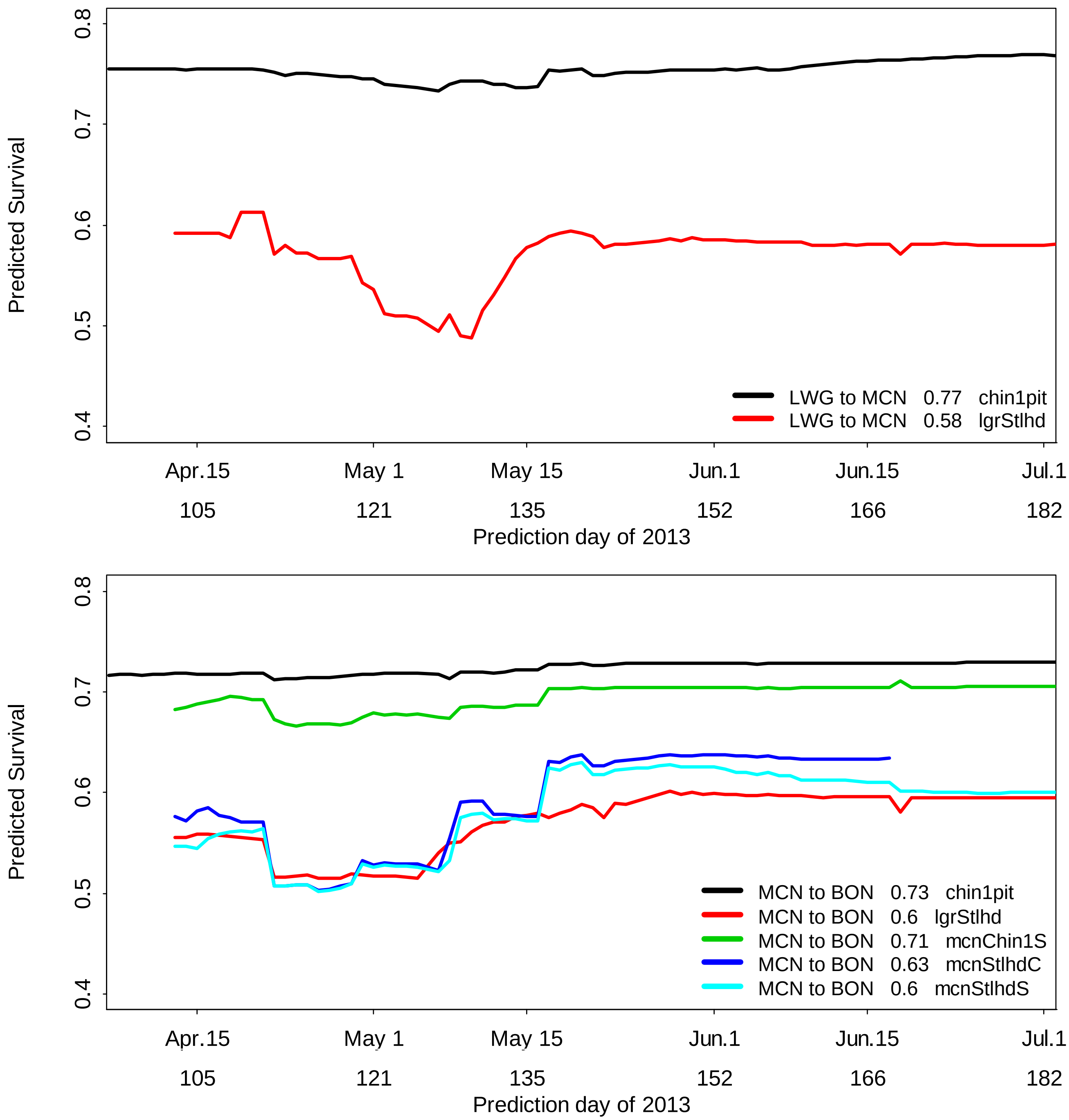


Figure 2 Predicted survivals from LWG to MCN and from MCN to BON for each stock as the season progressed.

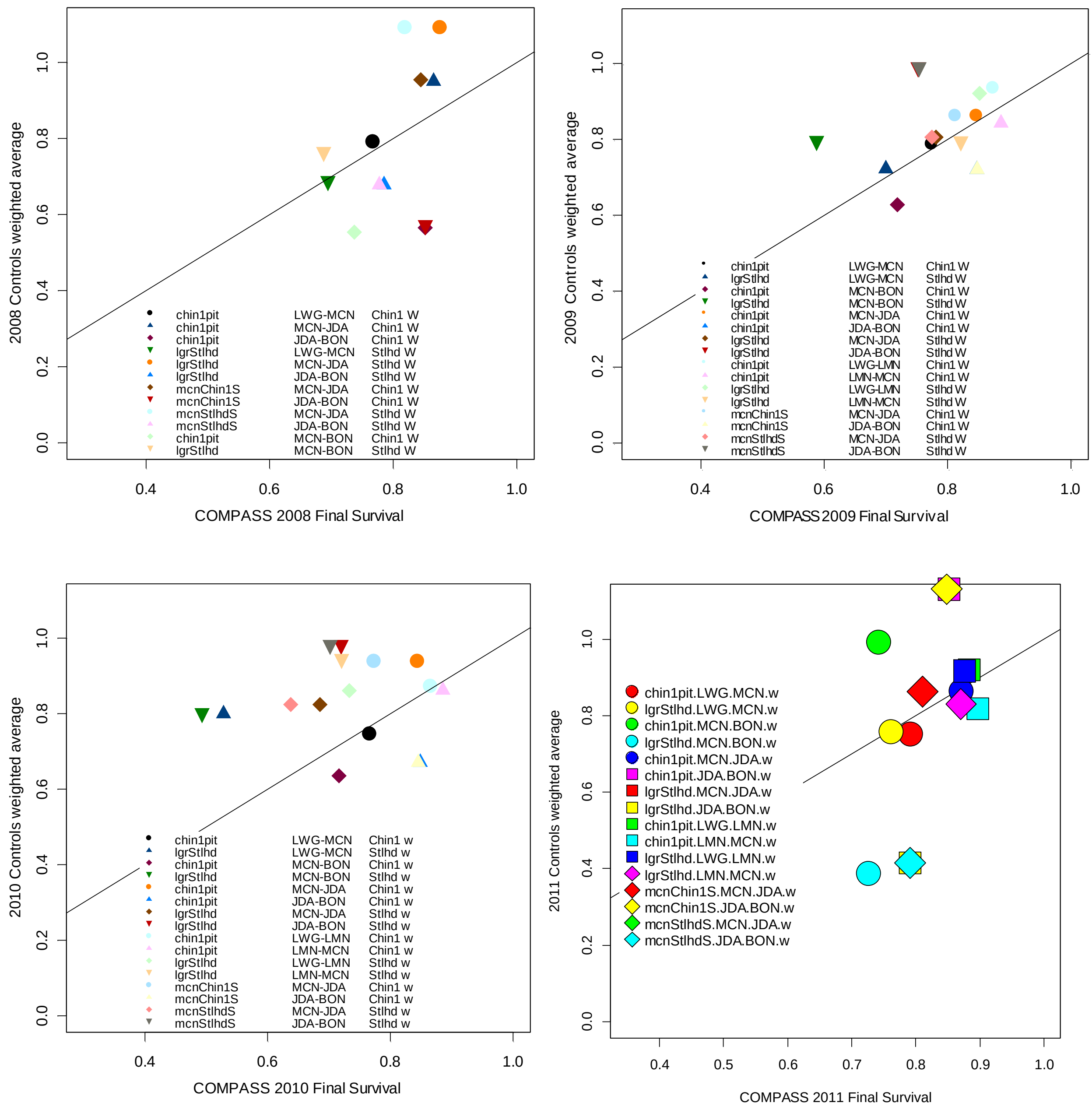


Figure 3 Comparison of control survival data against COMPASS-generated survivals from 2008 - 2013. The 1:1 line is shown in each plot. Axes are comparable between plots. There are four calibrations available to COMPASS: Steelhead and Chinook in either the lower Snake River or the mainstem Columbia River. lgrStlhd from JDA to BON is identical to mcnStlhdS from JDA to BON. Chin1pit shown with circles, lgrstlhd with squares.

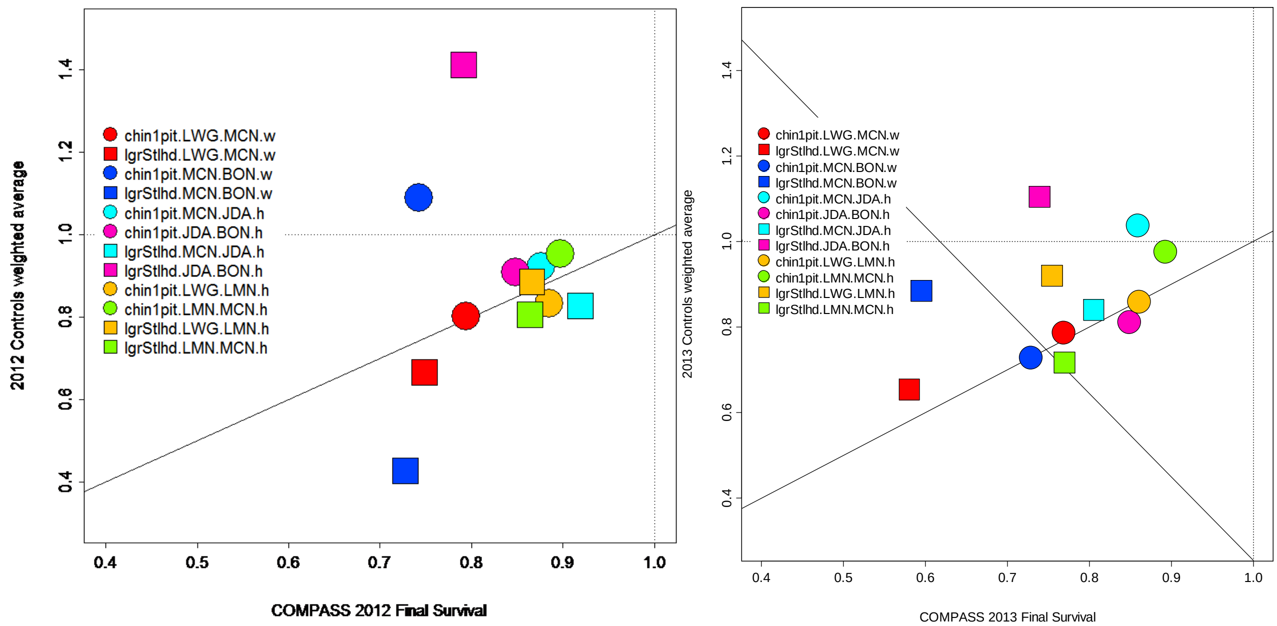


Figure 4 continued.

Summary and Discussion

Prediction of travel and survival is challenging. Broadly, these challenges relate to environmental conditions, stock-specific calibrations and bias in observations. Unfortunately, they cannot always be clearly distinguished.

River Conditions: Flow and Spill

In order to model the movements and survival of fish in the river, COMPASS requires environmental conditions for each day of the year, principally flow, spill and temperature. Egregious errors in flow prediction could make a meaningful difference in passage and survival predictions. Preseason predictions of water must be used with relevant updates made as the season progresses. These are obtained from flow forecasts provided by the Bonneville Power Administration, with observations (updated daily from DART @ http://www.cbr.washington.edu/dart/river.html). In 2013, flow conditions at both LWG and BON during the main part of the migration (~April 10 to May 30, days 100 to 150 at LWG) were mostly below the 10 year average (Figure 4). There were, however, two very high flow spikes during the migration period. These spikes in the flow are rarely predicted in detail. Figure 6 shows available early flow forecasts from April 3 and May 3 (days 93 and 123), and the final observations at LWG and BON dams.

Using the earliest available (March) flow predictions and hindsight knowledge of the exact arrivals at Lower Granite Dam, we ran the model to specifically address the importance of the pre-season flow predictions. MAD was computed with eq(3). The differences in timing and/or survival are not judged against each other but are compared to the final passage observations and survival controls. These special model runs called Pre-Post Runs are compared to the Post (or Final) Run when all known fish passage and environmental data can be used for a retrospective of the year. Differences between these two runs show the importance of the pre-season flow predictions (Figure 8)

Observations

Errors in model-to-data timing comparisons are often related to problems in detecting fish as they pass the dam. This has been a problem for years (Beer et al. 2007) and continues to be so. Spill variability is related to observation variability because it creates a bias over time in the proportion of fish passing the detectors, and skews the passage distributions. When cumulative passage curves at adjacent dams touch or cross in time series plots, it is an indicator of detection bias (see Appendix 1: Observed Cumulative Counts). A *change during the run* in spill efficiency, fish guidance efficiency or any other influence on dam passage routes can create this.

Second, when downstream detectors count more fish than those upstream of it then fish are getting through the upper dam(s) without detection (see Table 2 and Appendix 1: Observed Cumulative Counts). This could happened due to variable configuration of the dams, differential spill percentage encountered by the cohort as it passes downstream, or variability in the efficiency of moving fish into the bypass system. Figure 10 illustrates the anomalous observations well for the lgrStlhd which appear to be increasing in numbers from LWG to LGS and then LMN.

RealTime inputs

The inputs from program RealTime are based on observations and extrapolated forward in time so that a complete release prediction is available for COMPASS. There is not yet any way to precisely anticipate the fish arrivals, so RealTime's pattern matching algorithm uses all to-date observations of fish in the bypass system at the release dams and compares the available information to historical patterns. In addition, the observations of counts of fish in the bypass system are modified daily according to an estimate of the site's bypass efficiency. This is one reason the prediction and the observation do not match exactly at the release dams (MCN and LWG) and there may be differences in median passage day with MAD > 0%. The input distribution on any given day is the best available but may be significantly different from the actual distribution which is not estimated until the end of the season. In 2008, the chin1pit group of fish was unimodal, in 2009 bi-modal and in 2010 and 2011, tri-modal. In 2012, there was a strong initial mode and a smaller secondary one. Steelhead were bi-modal in 2012 as in 2010, but uni-modal in 2011. At LWG in 2013 lgrStlhd and chin1pit are essentially unimodal.

In the early season, predictions of the run distribution are always unimodal. Since the distribution is recomputed daily as fish arrive, the median arrival day is not known exactly and therefore MAD at the release site can be significant, although it is generally lower than at downstream locations. In fact, MADs for chin1pit and lgrStlhd at LWG are 6.5 and 2.5 respectively (Table 6). In Figure 9 it is apparent that the prediction of passage is pushed later in time at mid-run for Chinook (Note where the red line moves horizontally or dips down). Skewed predictions are biased inputs to COMPASS that propagate downstream. Since COMPASS predictions at downstream locations are compared to the observations, input errors are propagated through model results. Multi-modal distributions at release tend to be smoother at downstream locations due to spreading of the population controlled by specific parameters in the input file.

Travel-time Calibrations

In principle, the Post predictions of travel time and survival should be the best possible. Although it is a hindcast of the passage, it is also a measure of the effectiveness of the calibration in terms of a validation. As a timing assessment, it has the best possible inputs: observations of all conditions in the system and the correct distribution of fish at the uppermost dam. Using the final run as the prediction of each day's percentiles and computing MAD gives our best possible measure of the model's ability to anticipate the timing of the fish: Final-Day MAD (see Table 8). This does not always improve and the reasons for that are not necessarily consistent, for example a survival bias and an observation bias could reinforce or compensate for each other.

If any travel calibrations are incorrect, it would appear as a consistent or increasing bias in travel time estimation (see Appendix 2: Timing Observations and Predictions). If the discrepancy gets worse, then the travel-time modeling may be suspect. Having the prediction curves lie to one side of the corresponding observations and steadily increasing may suggest a systematic error such as the calibration. Final-MAD for the both the chin1pit and lgrStlhd do increase steadily downstream of LWG. Another source of timing errors could be that the fish have different rates in the different reservoirs. There are two migration rate equations used distinctly for the upper and lower portions of the river, but further discrimination may not ever be possible with the available data. In the early season, poor timing predictions are at least in part due to the assumed input distribution of fish at LWG which are then propagated through the system, but at the end of the season, the distribution of fish should be well known.

Survival Calibrations

Survival modeling is compared to the control-release data. Our discussion focuses on the wild fish but hatchery fish are also illustrated in Appendix 4: Survival Predictions with Data Controls. Modeled survival of wild Chinook is comparable to the data for chin1pit to MCN and to BON (Figure 18, Figure 19). For the lgrStlhd, the results are much less consistent partially due to low numbers although the hatchery fish have good correspondence between the survival estimates. Understanding survival-sensitive processes is essential to meaningful calibrations for COMPASS and reconciling differences between the two methods of evaluating survival: control-release studies and COMPASS modeling.

Annual Comparisons

A summary of several survival metrics from recent years using COMPASS (with NMFS 2008 calibration) and the control-release data. Retrospective runs using historic files *may* give slightly different results. These were the final results during the specified year and reflect the data conditions available during real-time forecasting season. The Chinook survivals have been remarkably flat while the steelhead survivals are low in 2010 and 2013.

Table 15 COMPASS and data survival point estimate comparisons since 2008.

Survival to BON	2013	2012	2011	2010	2009	2008
COMPASS Chinook	0.56	0.58	0.58	0.55	0.55	0.57
COMPASS Steelhead	0.35	0.55	0.56	0.27	0.41	0.48
Control Chinook	0.70*	0.67	0.42	0.48	0.50	0.37
Control Steelhead	0.59*	0.78	0.63	0.63	0.58	0.36

*product of point survivals from LWG to MCN and from MCN to BON

Additional Summary and Discussion Tables and Figures

Table 16 Comparison of passage and survival to BON showing the relative importance of the environmental predictions. MAD values in this table use the OneDay-MAD computation (eq(3)). The early in-season run is when both arrival and environment are predicted (early April). The post-season run is when both the arrival and environment are known. The Pre-Post run used predicted environmental conditions and known LWG arrival distributions.

	Runs	Env.	LWG Passage	Median Passage Day	COMPASS Survival to BON	MAD
Chin1	Early	Predicted	Predicted	142	54 %	3.8
	Post	Known	Known	144	56%	9.1
	Pre-Post*	Predicted	Known	144	57%	9.1
Stlhd	Early	Predicted	Predicted	139	33 %	4.4
	Post	Known	Known	144	35%	8.9
	Pre-Post*	Predicted	Known	143	37 %	8.8

*Early April water prediction & observed (final) fish arrival at LWG

Table 17 Difference in days between *final* predicted 10, 50 and 90 percentiles and the corresponding observed percentiles. Compare to Table 5.

Difference between Predicted 10% and Observed 10%						
	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	1	7	0	4	7	4
lgrStlhd	-2	3	-10	10	13	13
mcnChin1S	-	-	-	2	7	4
mcnStlhdC	-	-	-	0	7	9
mcnStlhdS	-	-	-	1	4	4
Difference between Predicted 50% and Observed 50%						
	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	-1	5	8	-11	-4	-13
lgrStlhd	1	3	3	7	7	7
mcnChin1S	-	-	-	2	3	2
mcnStlhdC	-	-	-	1	1	2
mcnStlhdS	-	-	-	1	1	1
Difference between Predicted 90% and Observed 90%						
	LWG	LGS	LMN	MCN	JDA	BON
chin1pit	1	5	8	-11	-4	-13
lgrStlhd	1	2	6	-3	5	-3
mcnChin1S	-	-	-	0	9	1
mcnStlhdC	-	-	-	-8	-3	-8
mcnStlhdS	-	-	-	0	9	-1

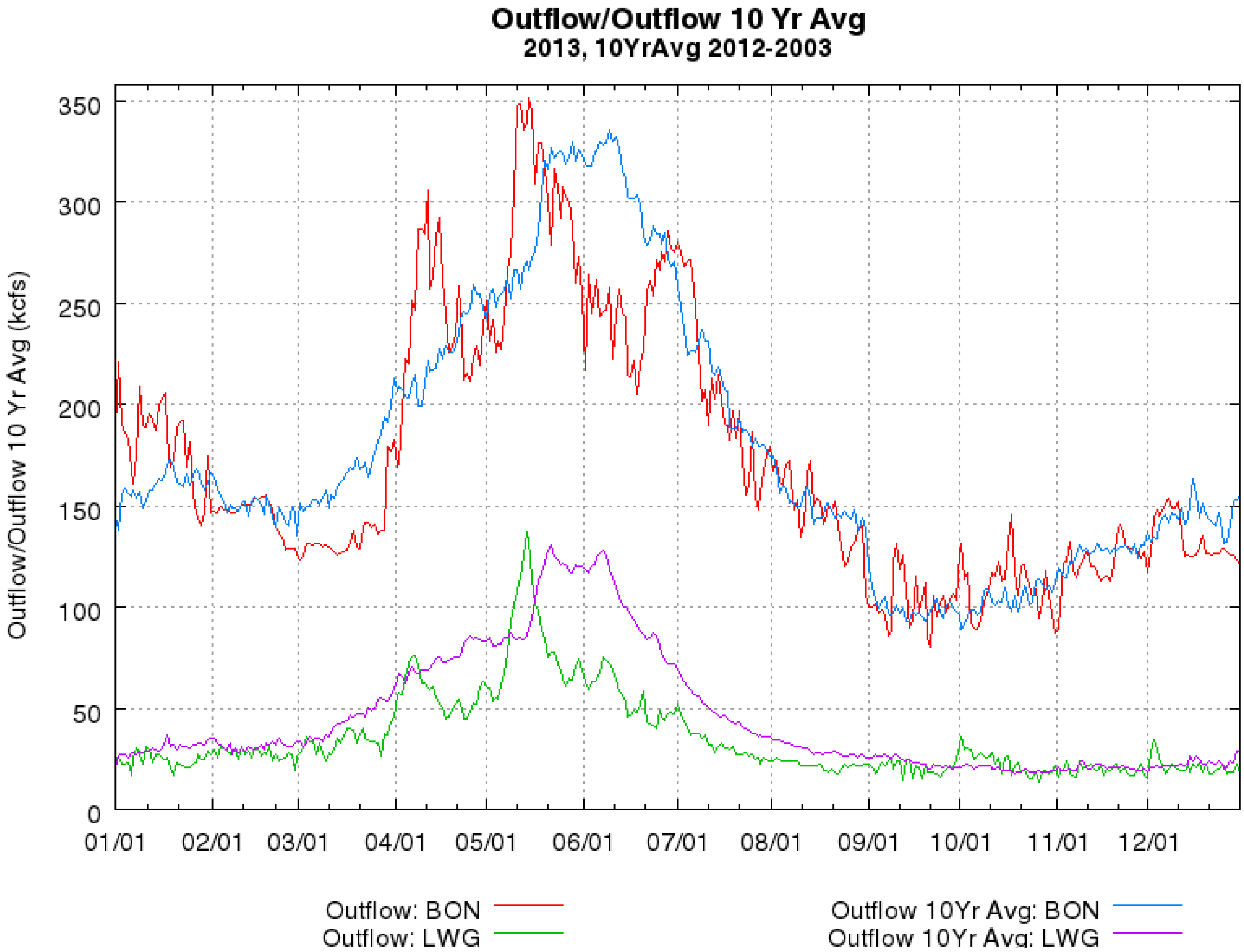


Figure 4 Comparisons of flows at LWG and BON in 2013 during the outmigration relative to the previous 10 year (2003-20012) average.

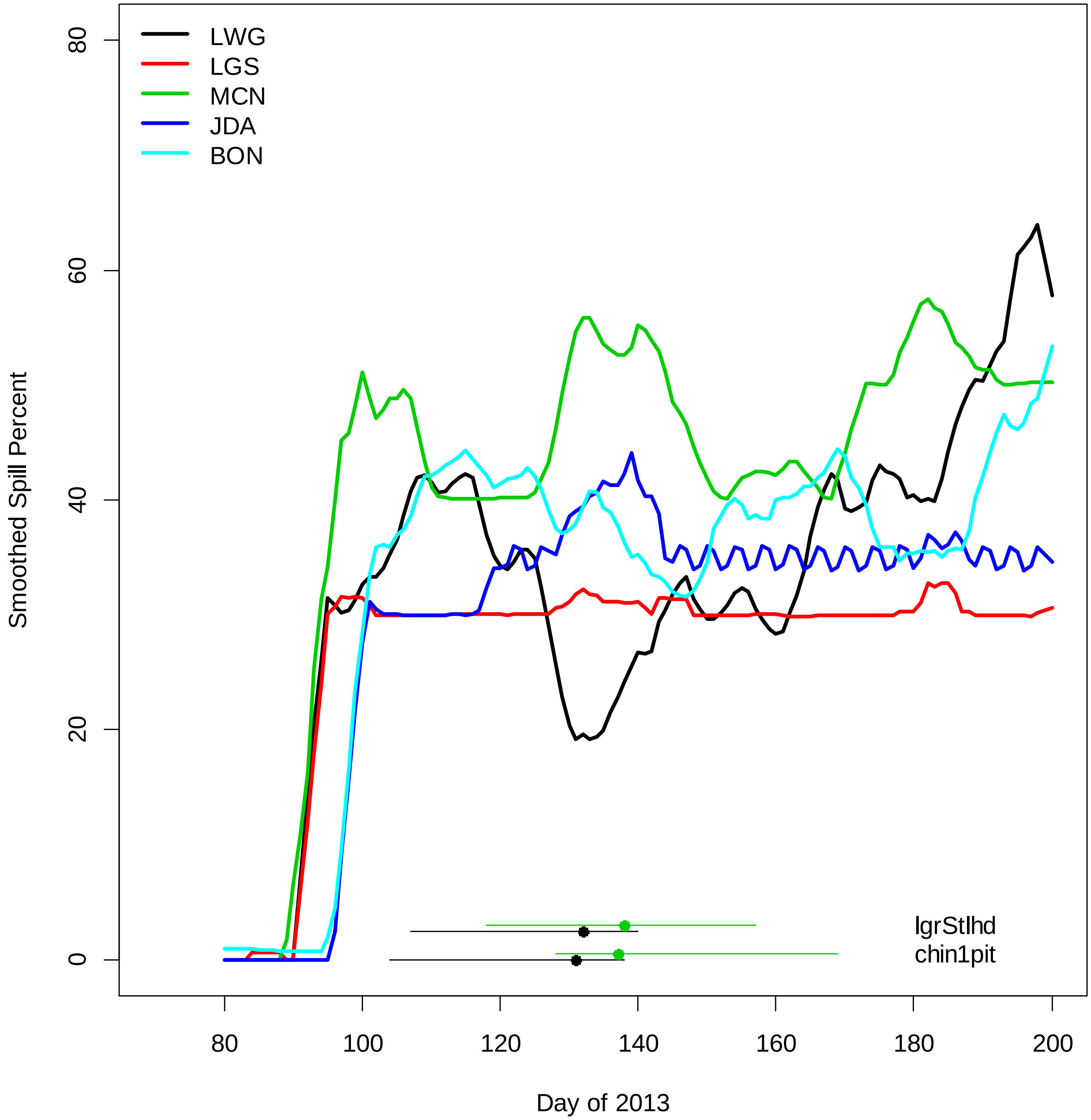


Figure 5 Spill percent (smoothed) at dams during passage in 2013. Stock abbreviations and whiskers of the middle 80% of the observed fish and median day (point) passage at LWG (black) and BON (green) at the bottom. We infer that the passage at intermediate dams as being between the first (LWG) and last (BON).

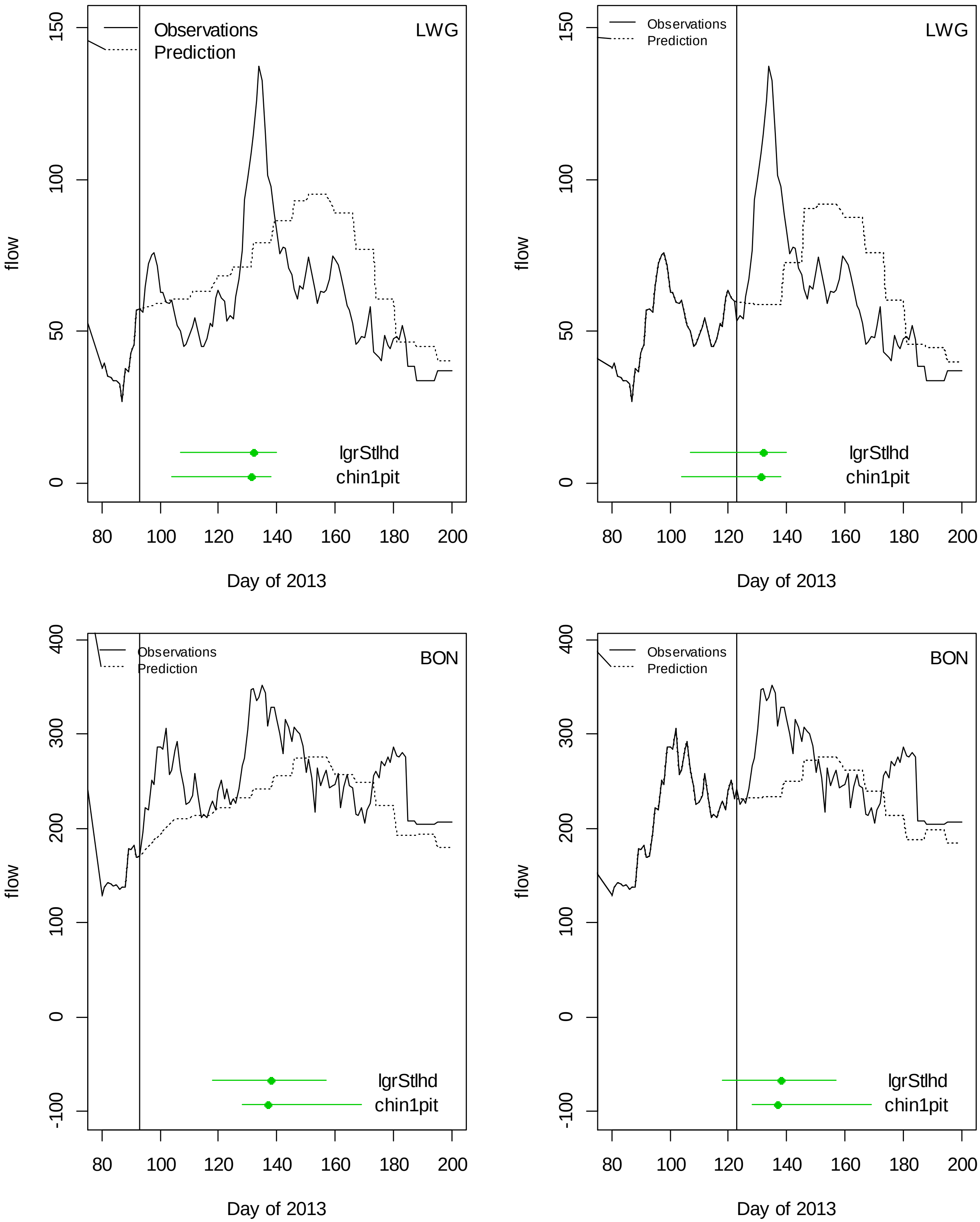


Figure 6 Predicted flow for 2013 made on April 3 and May 3 (day 93 and 123) and final observed flow at LWG and BON. Vertical lines show the prediction day. Passage metrics are at LWG and BON showing median day and 10% to 90% passage whiskers.

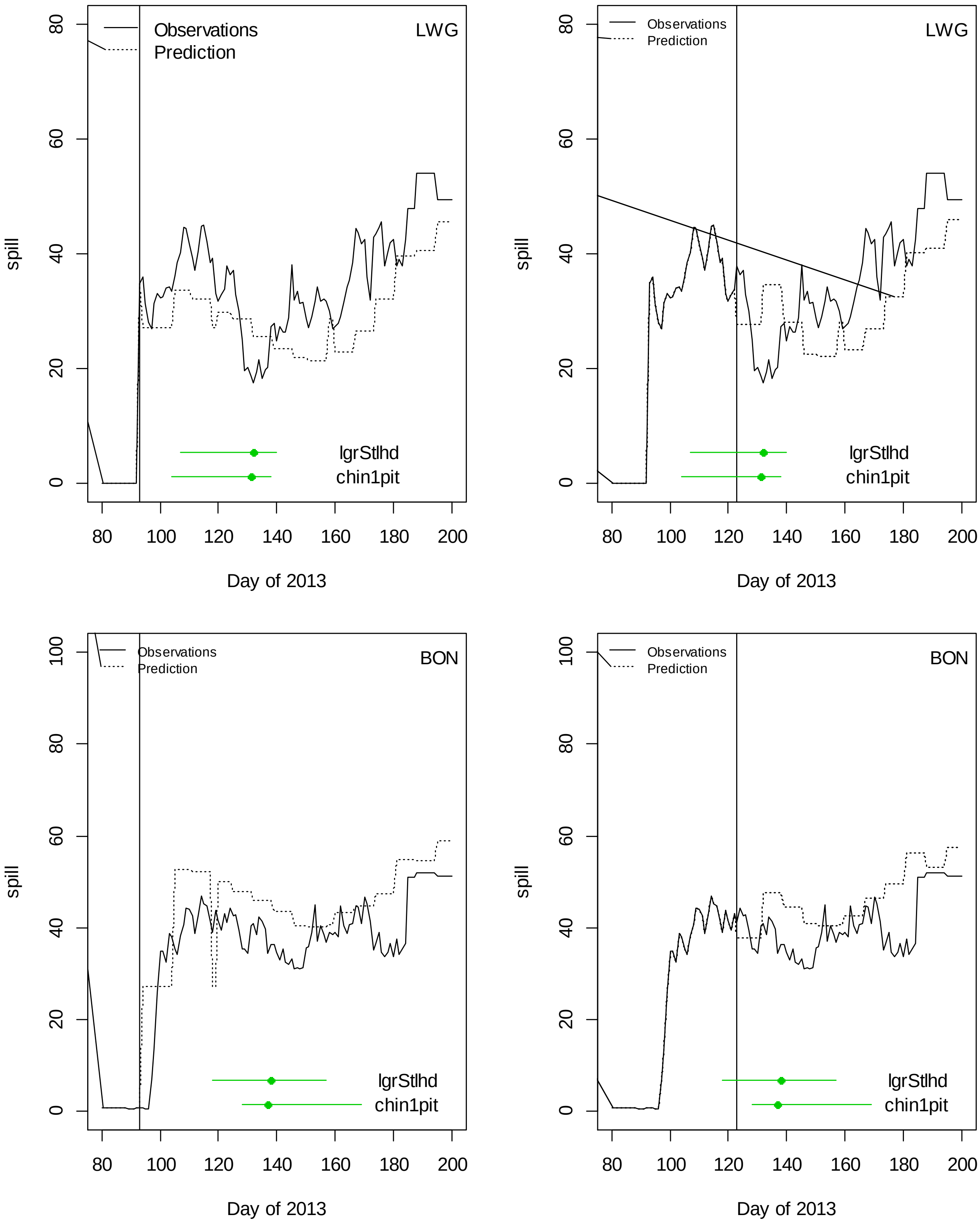


Figure 7 Predicted spill for 2013 made on April 3 and May 3 (day 93 and 123) and final observed spill at LWG and BON. Vertical lines show the prediction day. Spill volumes are explicitly stipulated at these two sites. Passage metrics are at LWG and BON showing median day and 10% to 90% passage whiskers)

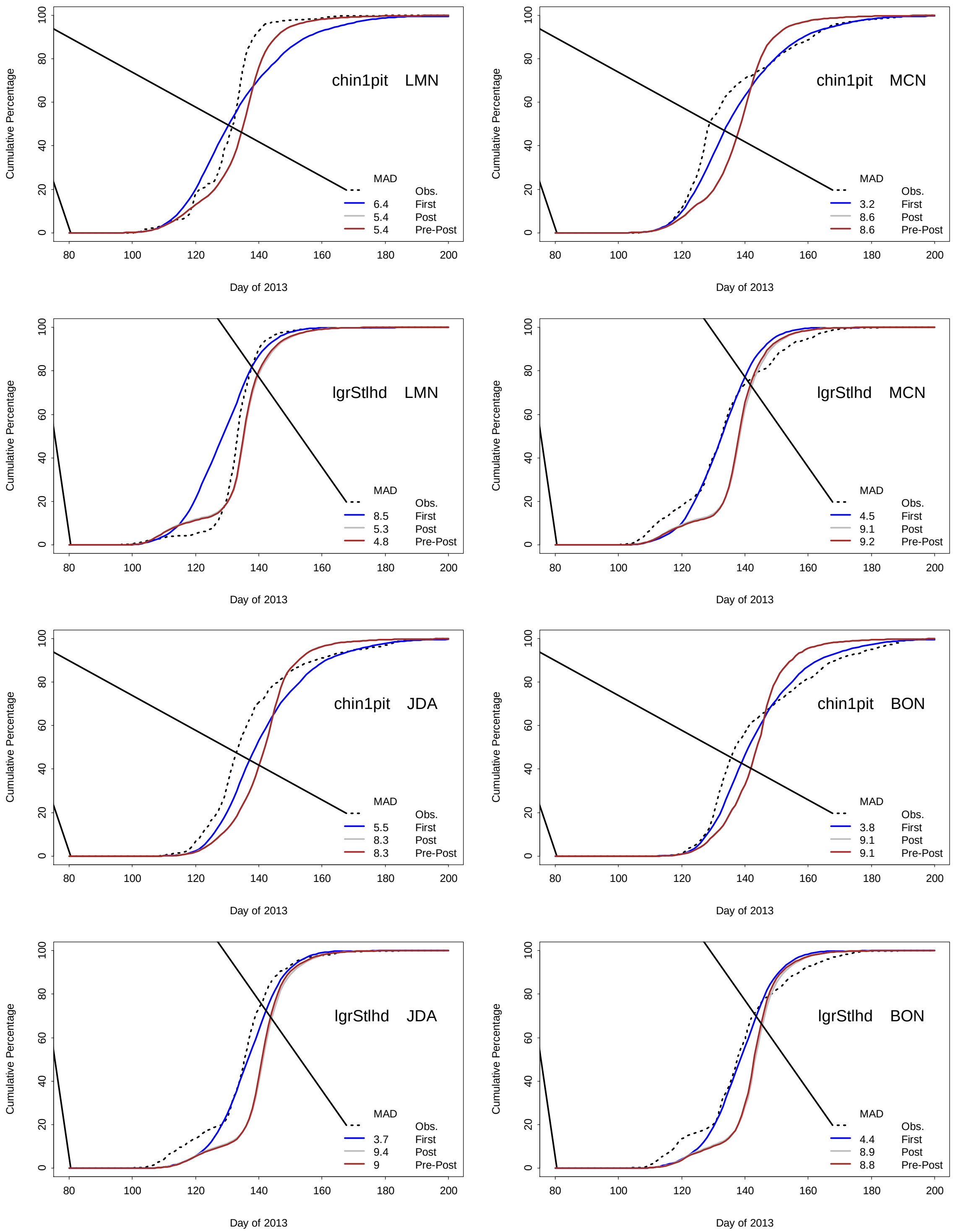
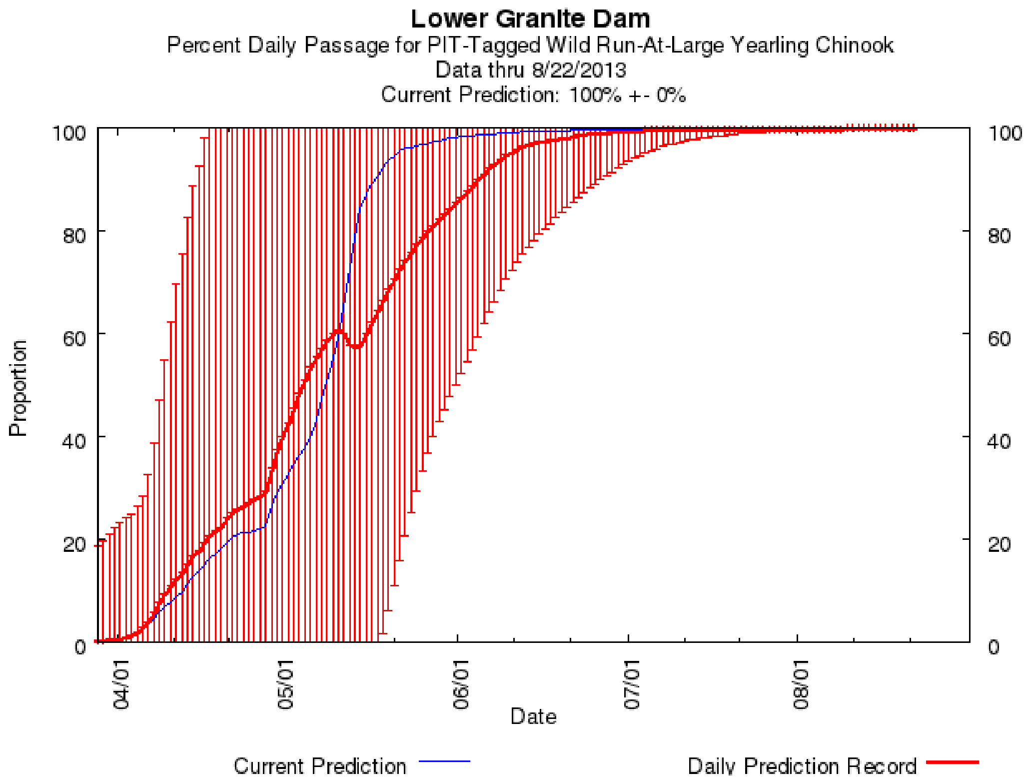


Figure 8 Comparison of LMN, MCN, JDA, and BON passage using three distinct COMPASS runs for chin1pit and lgrStlhd. "First" is the April 1 prediction based on anticipated arrivals and anticipated environmental conditions. "Post" uses all observations. "Pre-Post" uses the record of observed arrivals and the preseason environmental predictions from early April. Note: May 1 = Day 121.



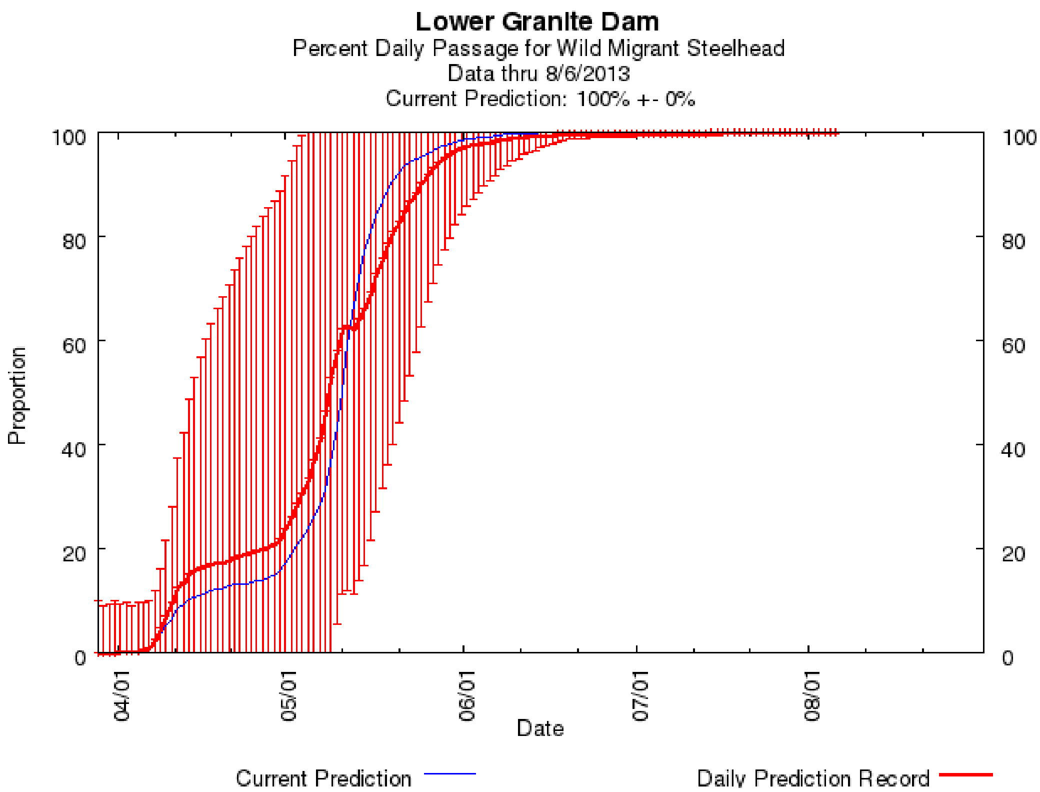


Figure 9 RealTime predictions and observations of Chinook and steelhead passing LWG in 2013 (see also http://www.cbr.washington.edu/crisprt/index_snake_pit.html). Vertical bars show the 95% confidence interval. The current prediction is the redistribution of the passage based on hindsight. Note: May 1 = Day 121.

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NMFS. 2008. "Remand of 2004 Biological Opinion on the Federal Columbia River Power System (FCRPS) including 19 Bureau of Reclamation Projects in the Columbia Basin (Revised pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon)." Retrieved August 18, 2010, from https://pcts.nmfs.noaa.gov/pls/pcts-pub/pcts_upload.summary_list_biop?p_id=27149.

Zabel, R.W. and 11 other authors. 2008. Comprehensive passage (COMPASS) model: a model of downstream migration and survival of juvenile salmonids through a hydropower system. Hydrobiologia. 609:289-300.

Appendix 1: Observed Cumulative Counts

First, the totals of each stock observed at the six dams in 2013 are shown (Figure 10). Then, the cumulative observations of stocks at counting dams are shown (Figure 11) separated by stock. Ordinate (y axis) scales vary. The lines span the entire range of the run from first detection to last.

Accurate profiles are expected to be sequenced with more fish upstream and generally decreasing downstream due to mortality or accidental transport. However, each location is more or less effective at detecting tagged fish in addition to variations in dam passage routing. Increases in counts from upstream to downstream are a clear indication that observation errors are significant. JDA and LGS are particularly suspect. The expected value is between the upper and lower values but is consistently (over years) anomalous.

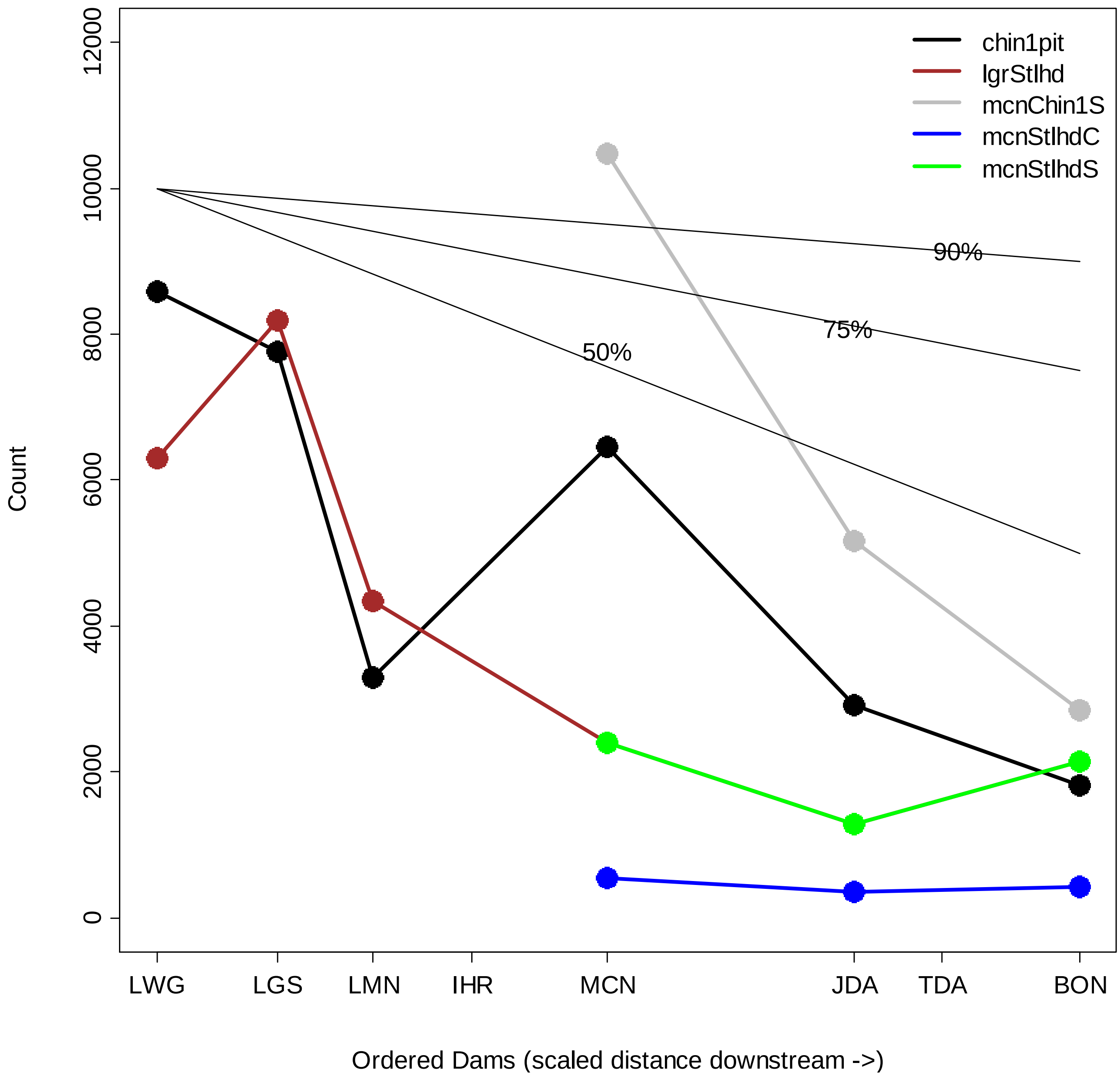


Figure 10 Stock counts at dams in 2013. Mortality between dams lowers the numbers from one dam to the next. Observation errors can make the numbers appear to increase or decrease from upstream to downstream. Below MCN, lgrStlhd are equivalent to mcnStlhdS.

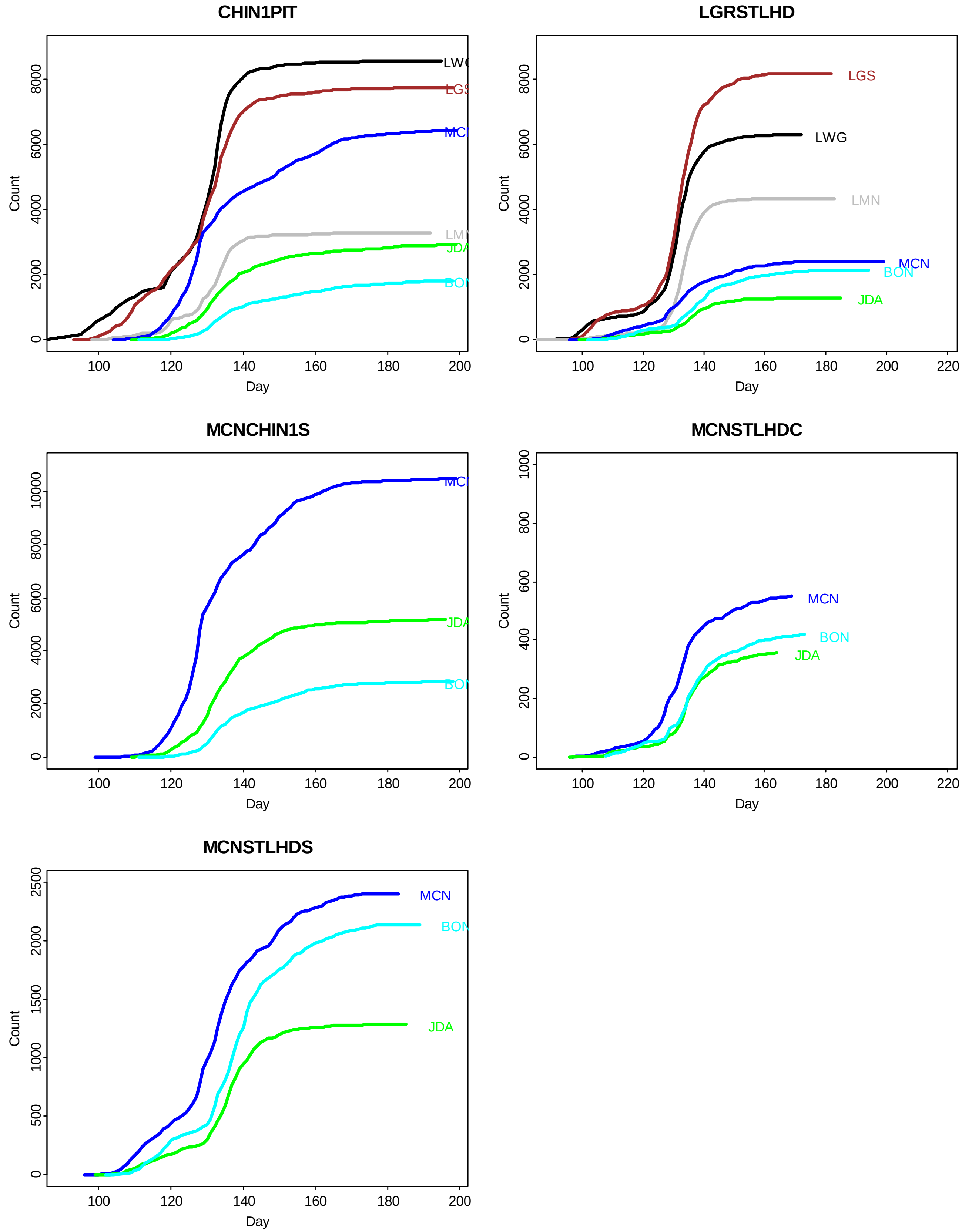


Figure 11 Passage Profiles by stock in 2013. Order of passage: LWG, LGS, LMN, MCN, JDA, BON.

Appendix 2: Timing Observations and Predictions

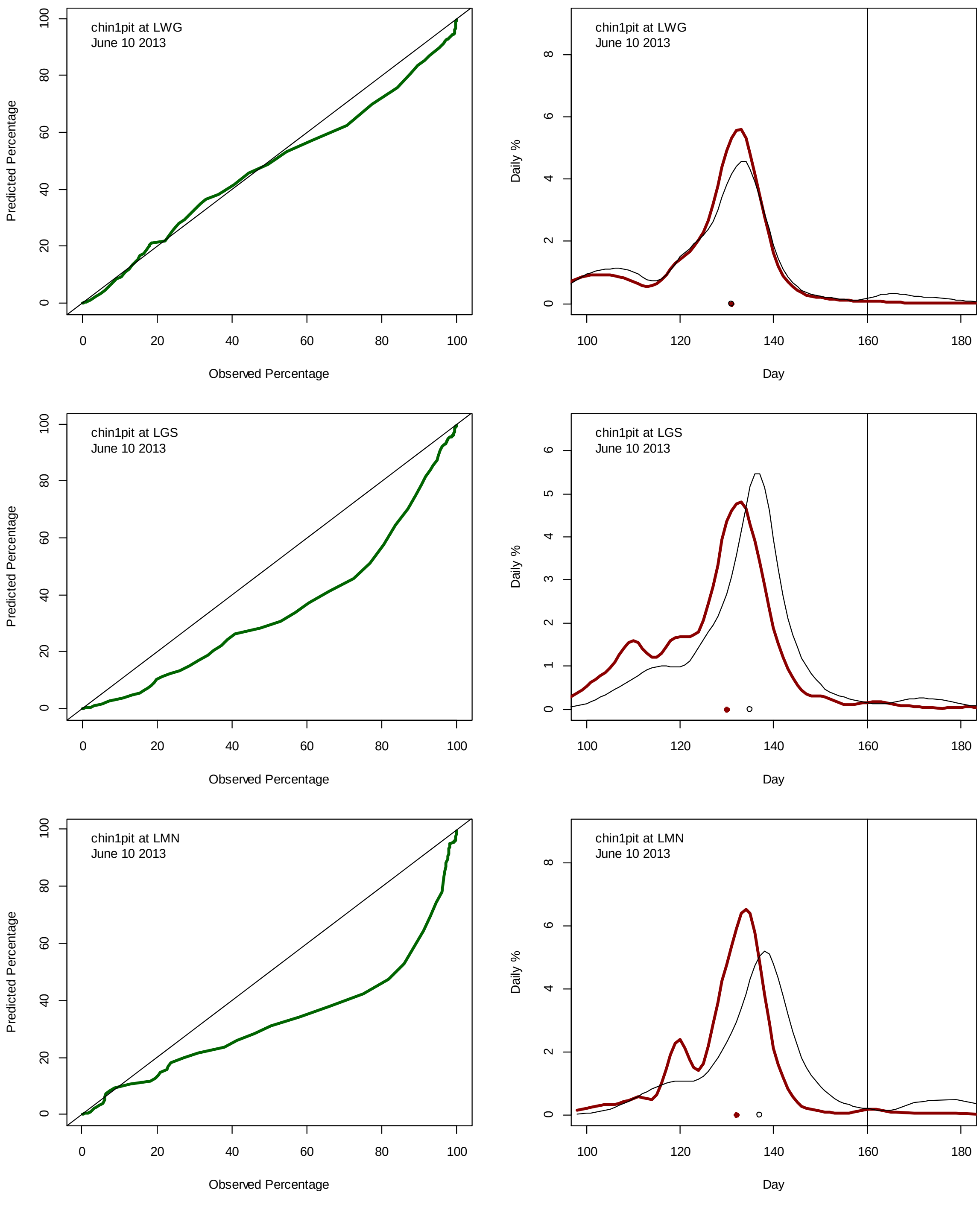


Figure 12 Assessment (at LWG, LGS, and LMN) of bias in observations for chin1pit compared to the June 10 prediction in 2013. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depict the median day for the observations (filled) and predictions (open).

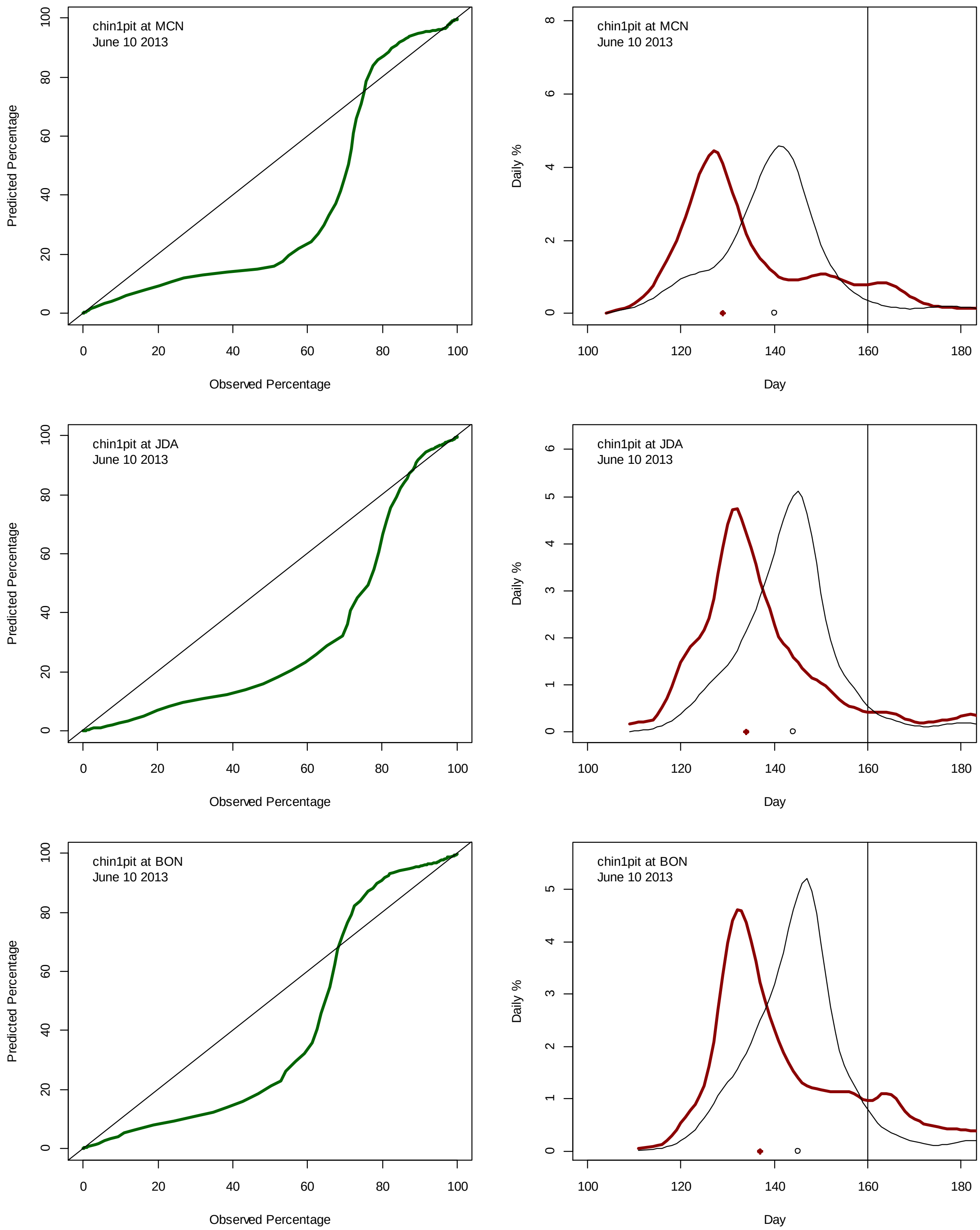


Figure 13 Assessment (at MCN, JDA, and BON) of bias in observations for chin1pit compared to the June 10 prediction. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depict the median day for the observations (filled) and predictions (open).

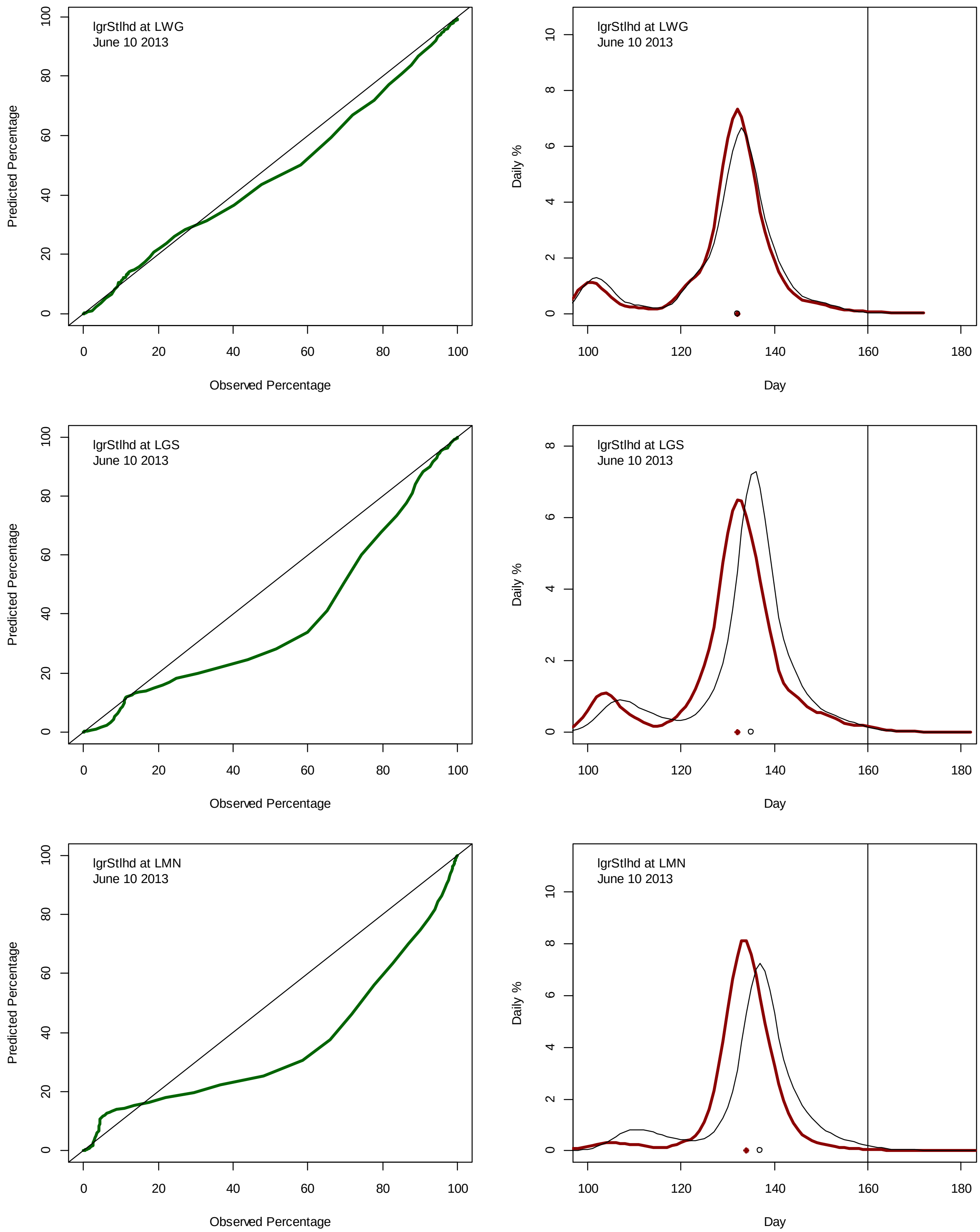


Figure 14 Assessment (at LWG, LGS, and LMN) of bias in observations for lgrStlhd compared to the June 10 prediction. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

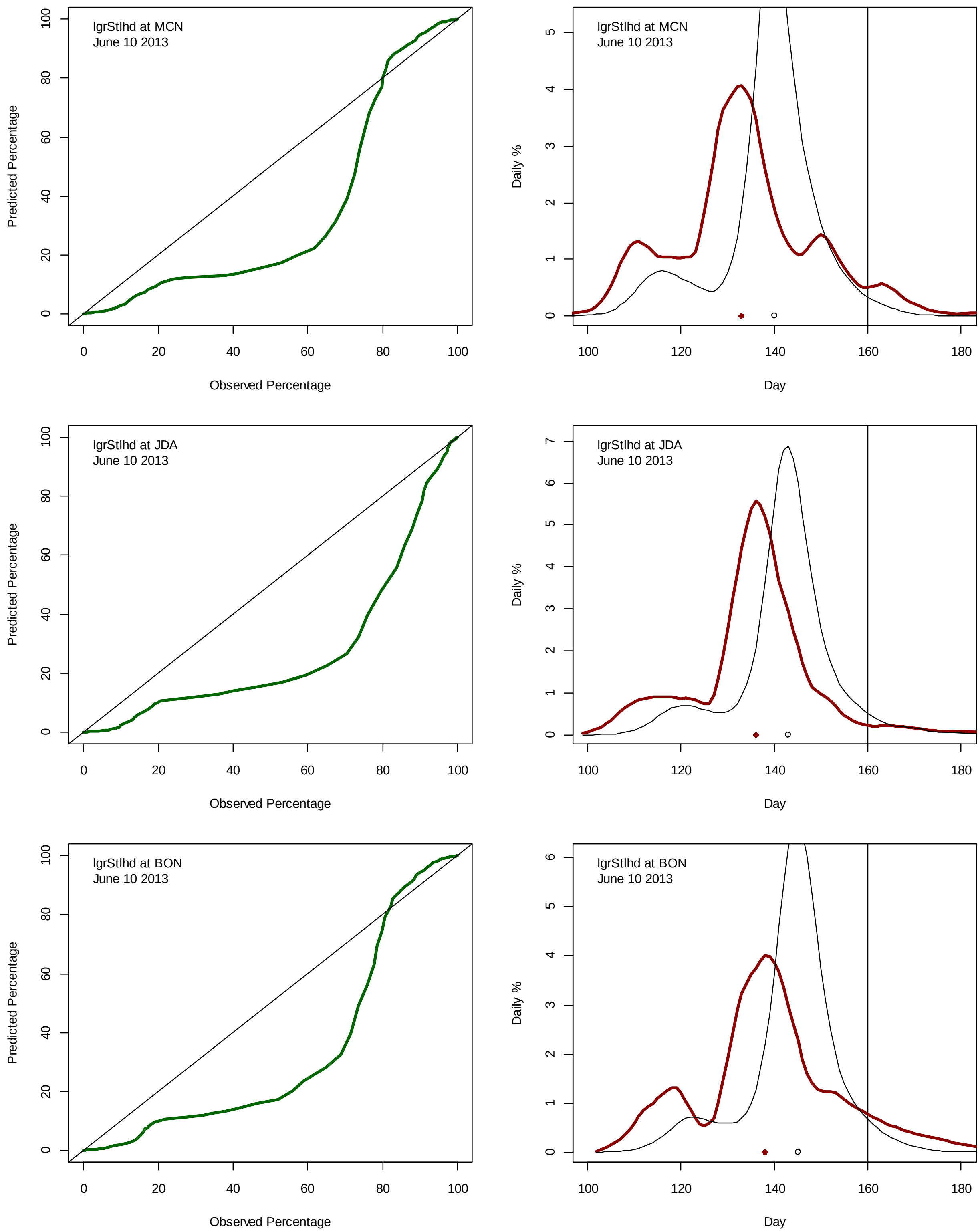


Figure 15 Assessment (at MCN, JDA, and BON) of bias in observations for lgrStlhd compared to the June 10 prediction. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

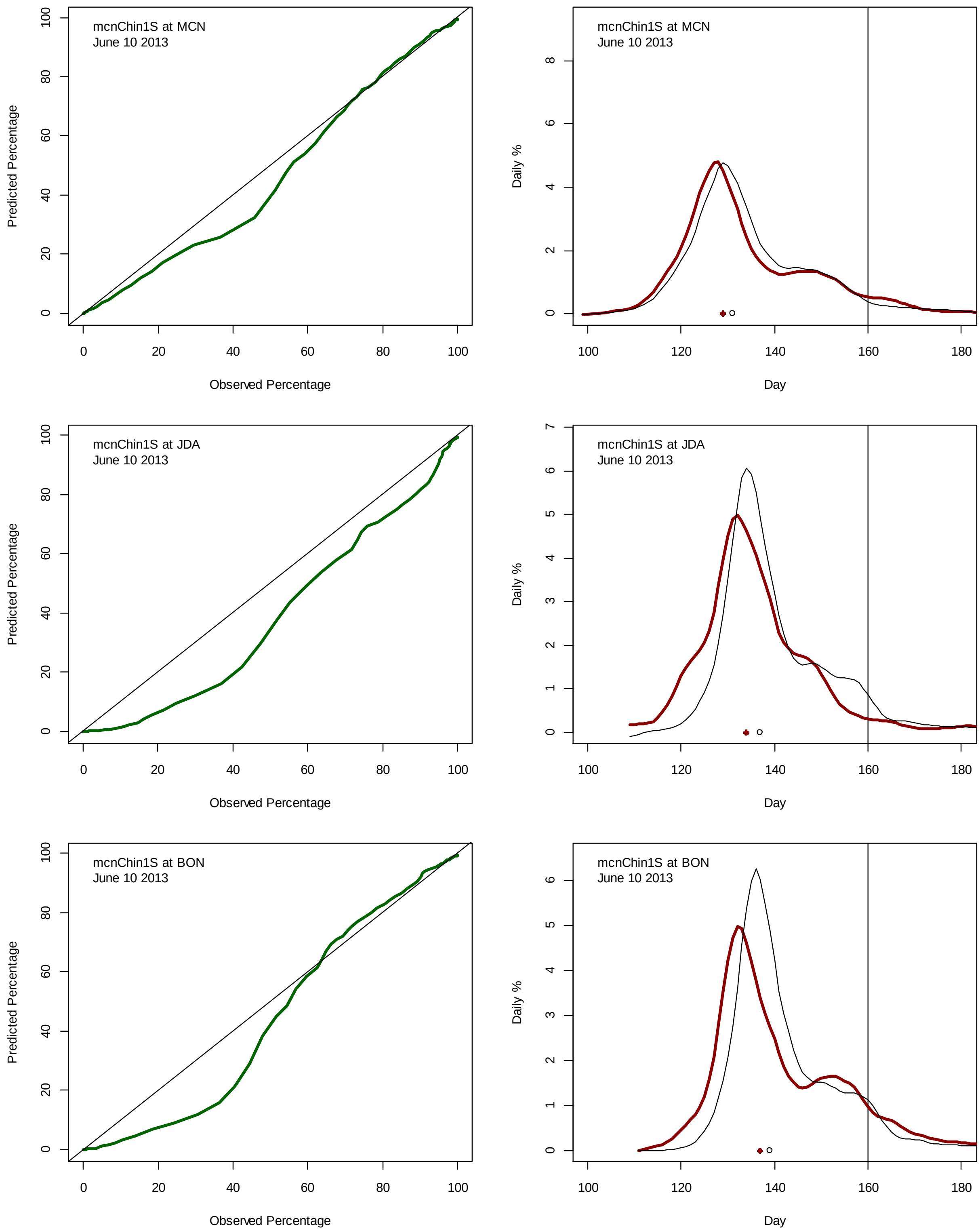


Figure 16 Assessment of bias in observations for mcnChin1S. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

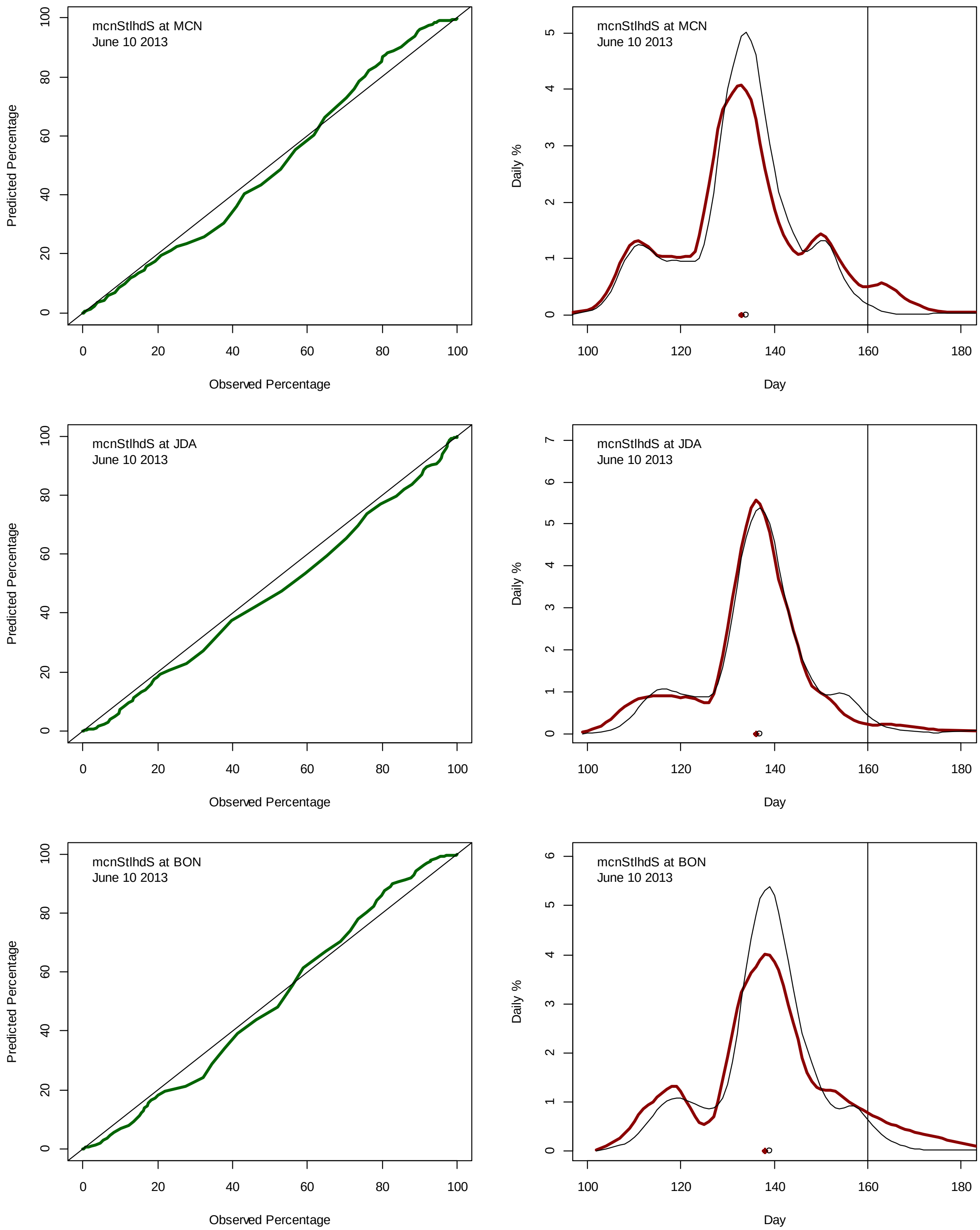


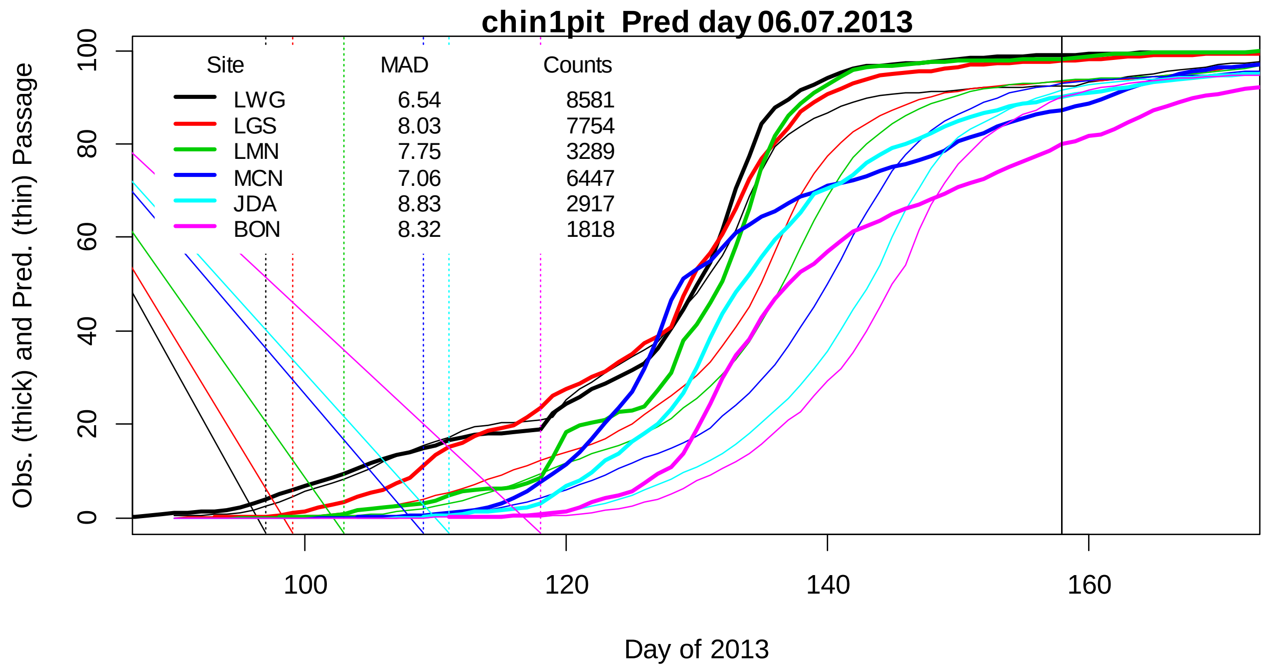
Figure 17 Assessment of bias in observations for mcnStlhdS. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

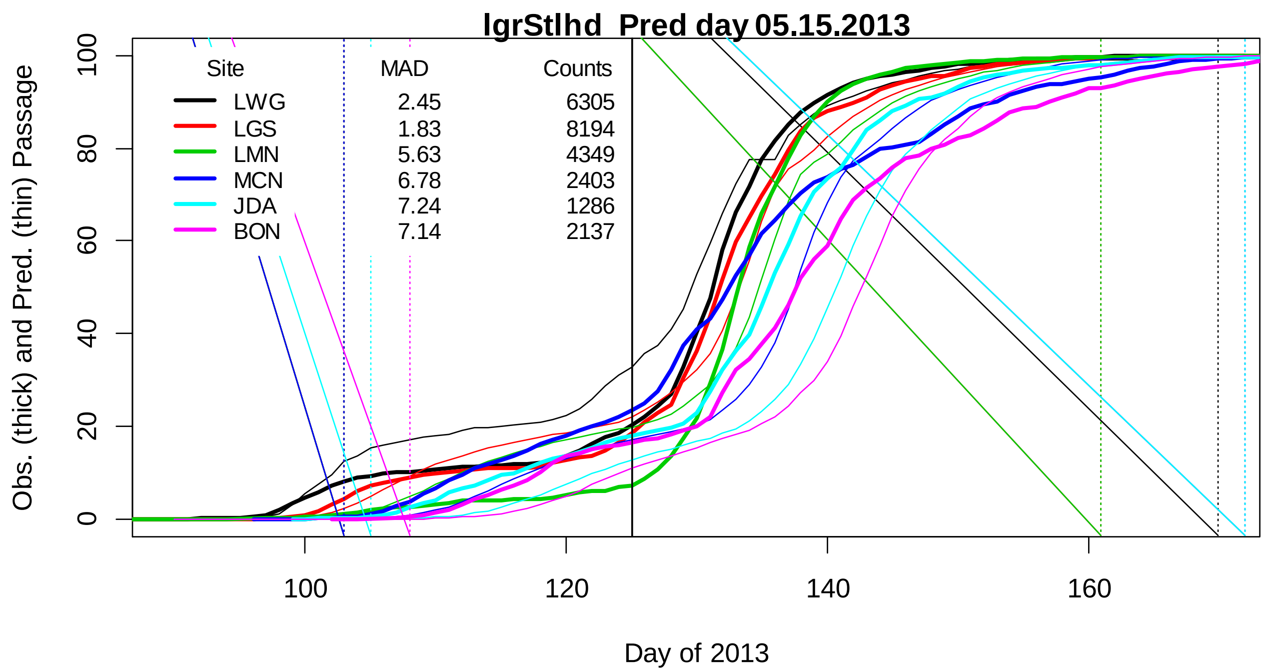
Appendix 3: Observations, Predictions and MAD

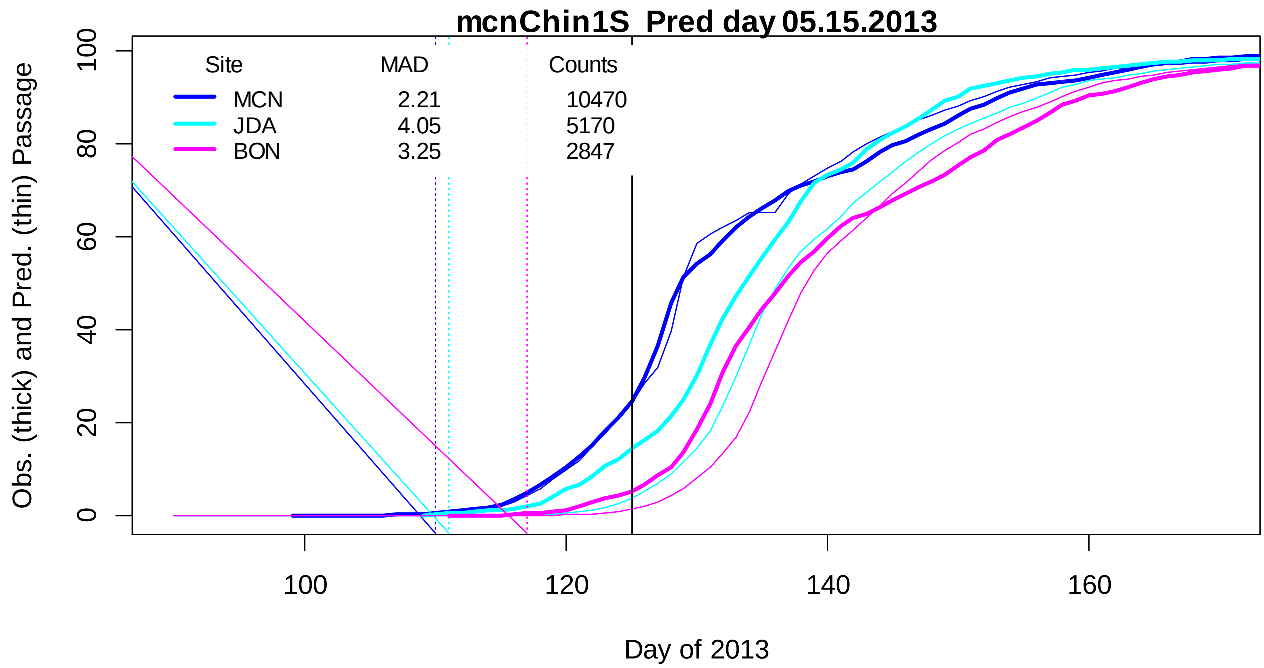
MAD day range calculations are made between 0.5 to 99.5 percentiles on both prediction and observation when possible. The graphs in this appendix depict all of the data used to compute MADs.

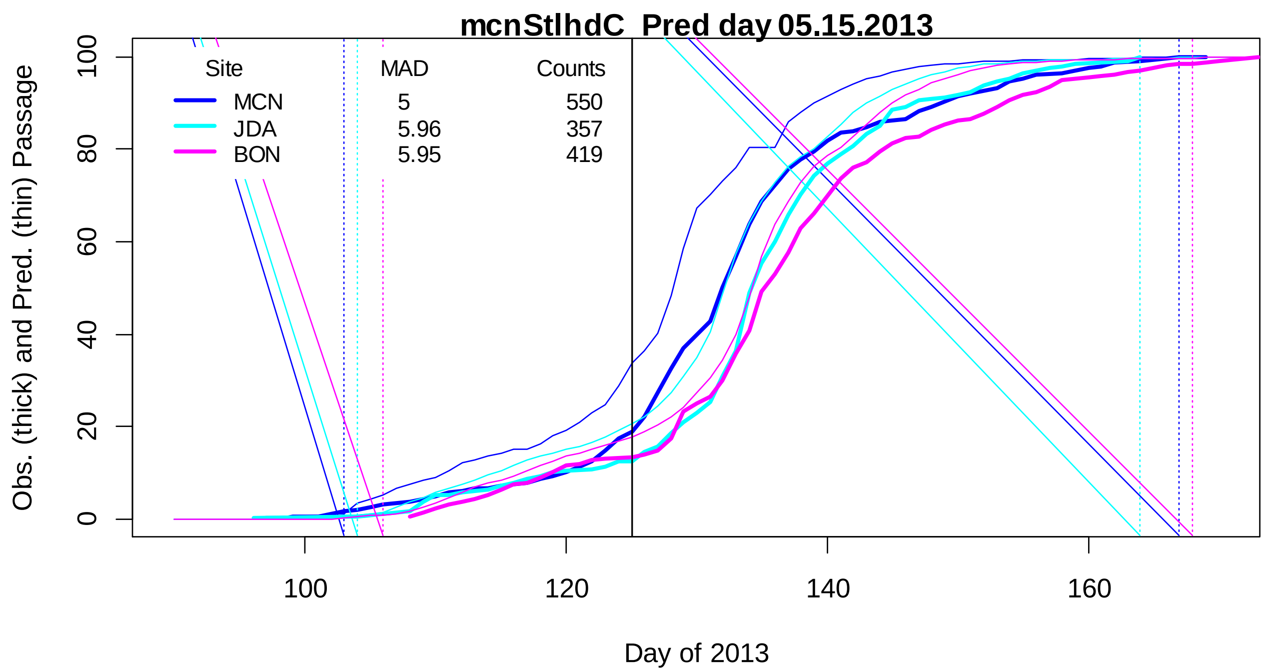
- All graphs have the same abscissa and ordinate ranges.
- Line color varies for different dams, each of which has a three letter code, followed by the MAD value (mean absolute deviation between observed and prediction passage percentage).
- Observations (Predictions) have the thicker (thinner) lines.
- Date ranges of the passage profiles depict the beginning and end days for the MAD calculations, i.e. between the 0.5 and 99.5 percentiles. (Vertical dotted lines)

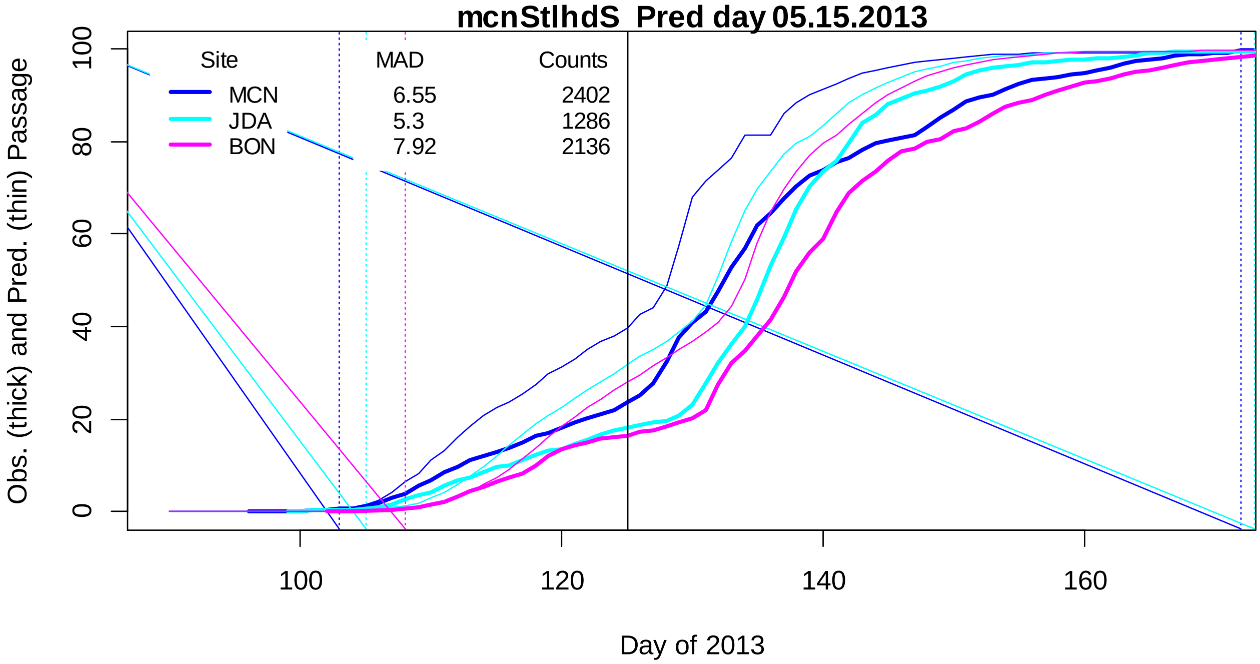
Prediction curve is the sequence of point predictions for the run and therefore can vary up or down from one day to the next. The uppermost dam arrivals are predicted by RealTime and COMPASS extrapolates that prediction downstream according to a migration model with movements controlled through calibrated parameters.


chin1pit Pred day 06.07.2013
Site
MAD
Counts
LWG
6.54
8581
LGS
8.03
7754
LMN
7.75
3289
MCN
7.06
6447
JDA
8.83
2917
BON
8.32
1818
Obs. (thick) and Pred. (thin) Passage
0
20
40
60
80
100
100
120
140
160
Day of 2013


lgrStlhd Pred day 05.15.2013
Site
MAD
Counts
LWG
2.45
6305
LGS
1.83
8194
LMN
5.63
4349
MCN
6.78
2403
JDA
7.24
1286
BON
7.14
2137
Obs. (thick) and Pred. (thin) Passage
0
20
40
60
80
100
100
120
140
160
Day of 2013


mcnChin1S Pred day 05.15.2013
Site
MAD
Counts
MCN
2.21
10470
JDA
4.05
5170
BON
3.25
2847
Obs. (thick) and Pred. (thin) Passage
0
20
40
60
80
100
120
140
160
Day of 2013


mcnStlhdC Pred day 05.15.2013
Site
MAD
Counts
MCN
5
550
JDA
5.96
357
BON
5.95
419
Obs. (thick) and Pred. (thin) Passage
0
20
40
60
80
100
120
140
160
Day of 2013


mcnStlhdS Pred day 05.15.2013
Site
MAD
Counts
MCN
6.55
2402
JDA
5.3
1286
BON
7.92
2136
Obs. (thick) and Pred. (thin) Passage
0
20
40
60
80
100
100
120
140
160
Day of 2013

Appendix 4: Survival Predictions with Data Controls

There are two types of graphics that follow
Type 1: COMPASS/RealTime output (CBR 2013)

- Predicted survival for fish released on that day is shown in green.
- Mean predicted travel time plus or minus one standard deviation in red.
- Median travel time (blue asterisk)
- Title indicates the overall survival for the cohort since it accounts for the number of fish on each day (not shown in this display).

Type 2: Summary of controlled release studies.

- Title has: “COMPASS Name” “Release and Recovery sites” “Controls-Species” “Controls - Rearing Type”. The Rearing types for the controls are chosen to match the observation stock.
- Black line is the time series of COMPASS prediction of the survival for the entire run made on each day (as opposed to daily survivals in the other plots).
- Control group Mean Survival (black circles) and Standard Errors (whiskers) are depicted for each release. The size of the circle is proportional to the number of fish released.
- Blue line shows the cumulative weighted average of the (data) survival estimates.
- The point estimates of survival are plotted at the *release day*, whereas the COMPASS line is referenced to the *prediction day*.
- “LGR” indicates Lower Granite Dam (a.k.a. LWG).

Other notes: Control release survival estimates are not available between all possible sites.
The time spans across the two types of graphs are very similar.

Day 80 = March 21
Day 130 = May 10
Day 180 = June 29

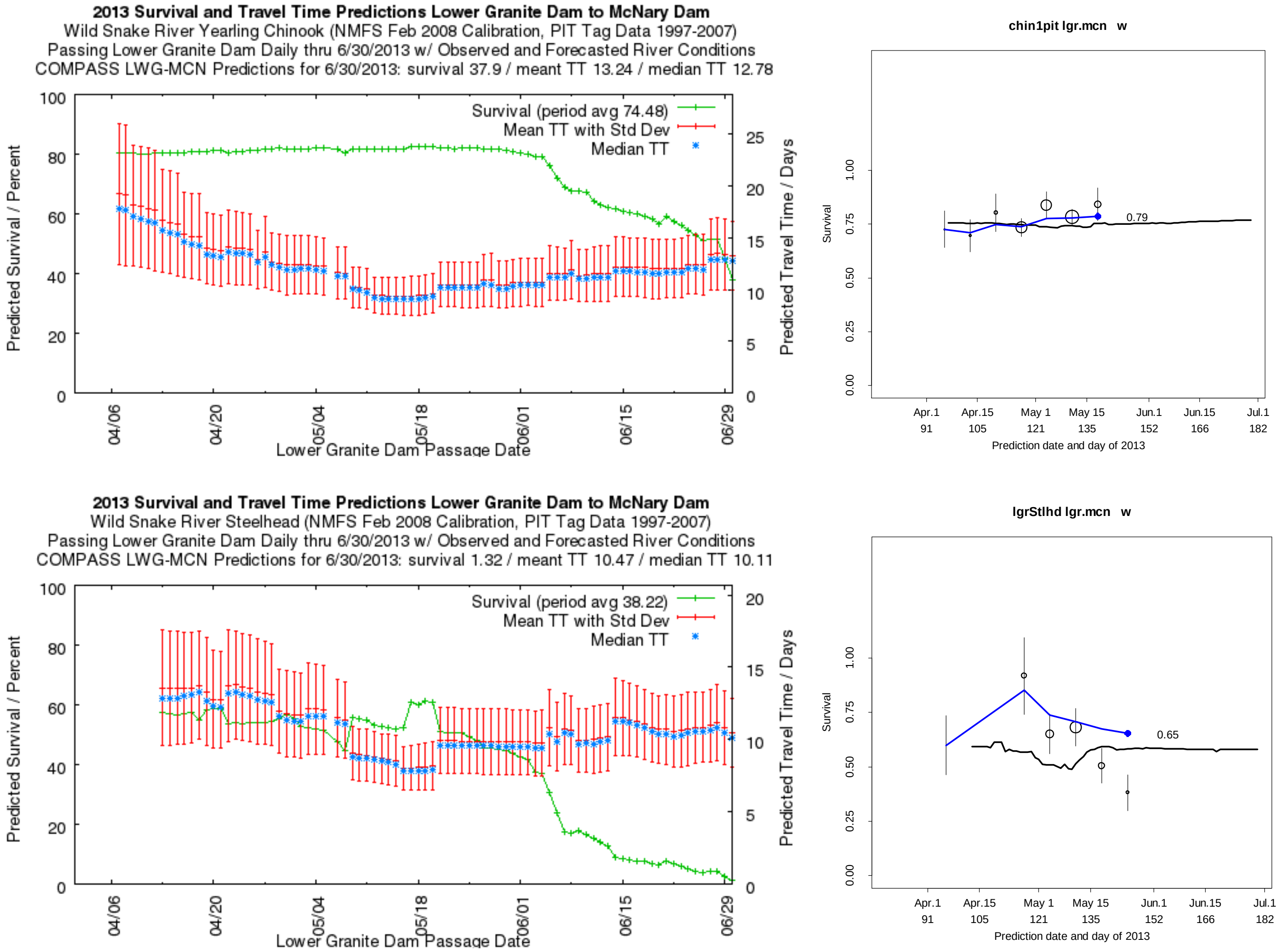


Figure 18 Daily survivals from LGR (LWG) to MCN of wild chin1pit (above) and lgrStlhd (below) using COMPASS (left side) and corresponding data controls (right side). Blue line is the weighted average survival. The seasonal change in COMPASS prediction shown as a black line.

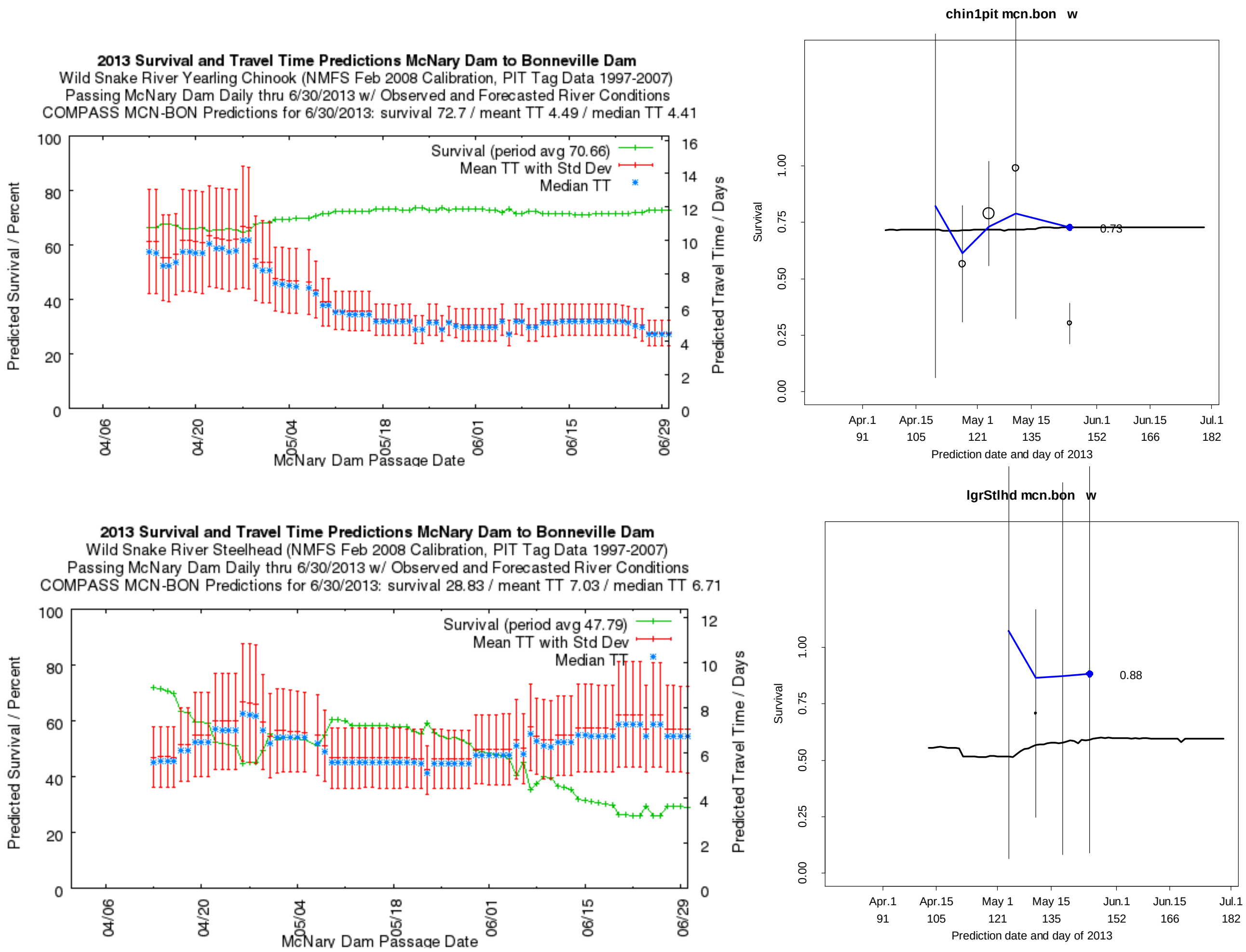


Figure 19 Daily survivals of wild chin1pit (above) and lgrStlhd (below) using COMPASS (left side) and corresponding data controls (right side) over the migration season in stages from MCN to BON. There is very little data on wild fish this year from in-river studies over this reach of river.). Blue line is the weighted average survival. The seasonal change in COMPASS prediction shown as a black line.

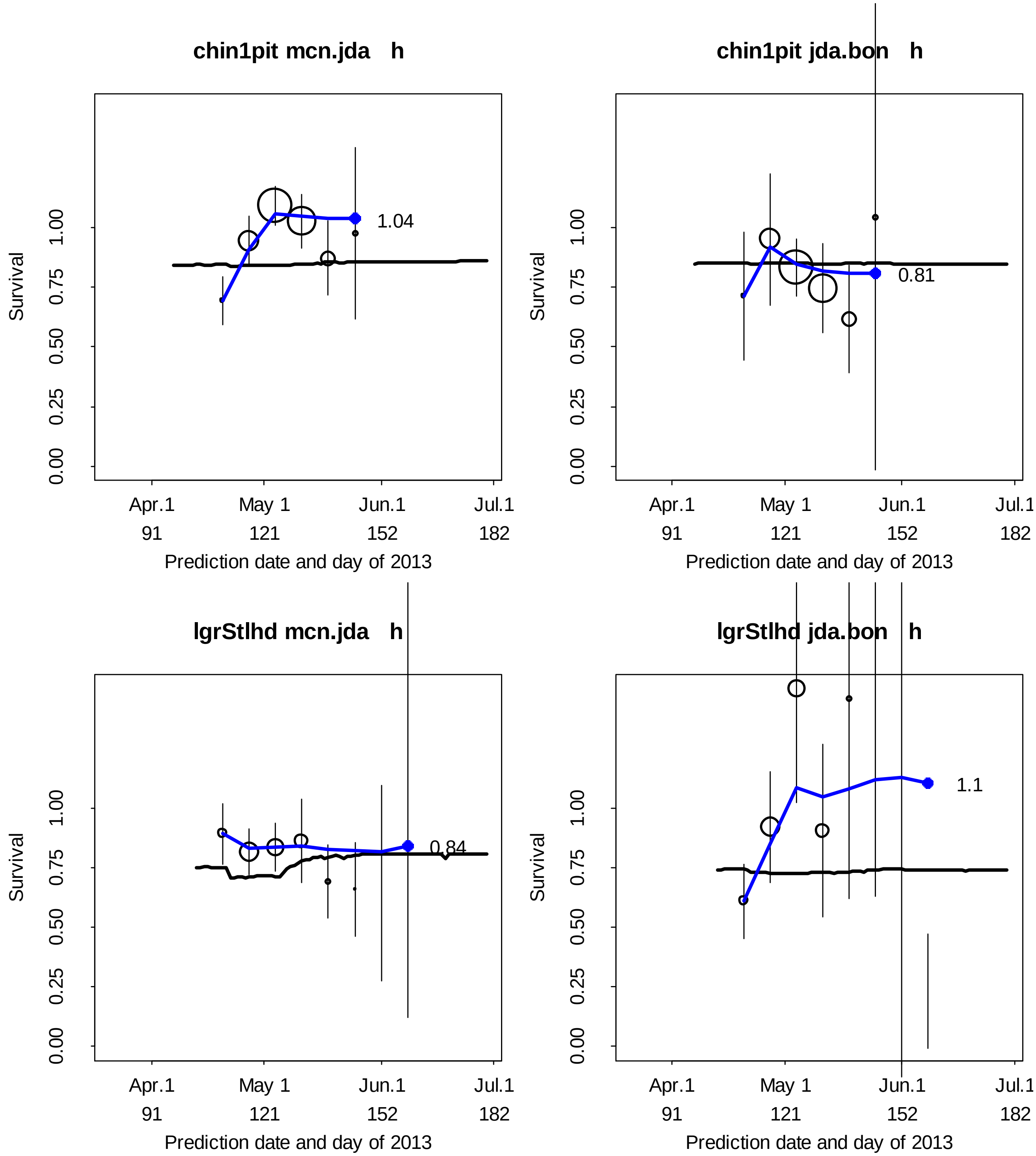


Figure 20 Part 1 Lower river COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for hatchery Chinook and steelhead. Circles scaled by release count and centered on release day, whiskers show standard error. Blue line shows release-count-weighted survival to date. Final count-weighted average survival written out as well.

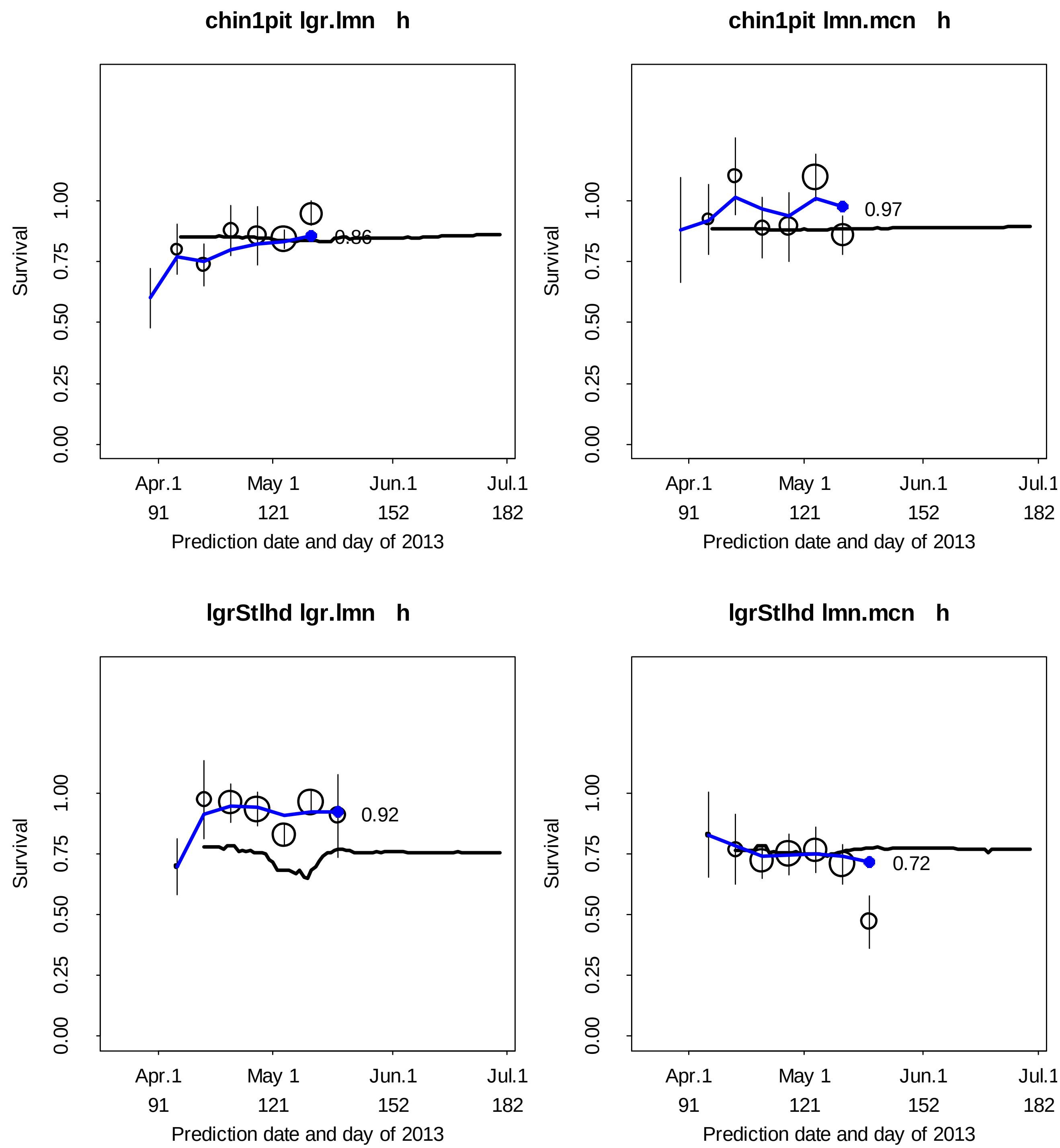
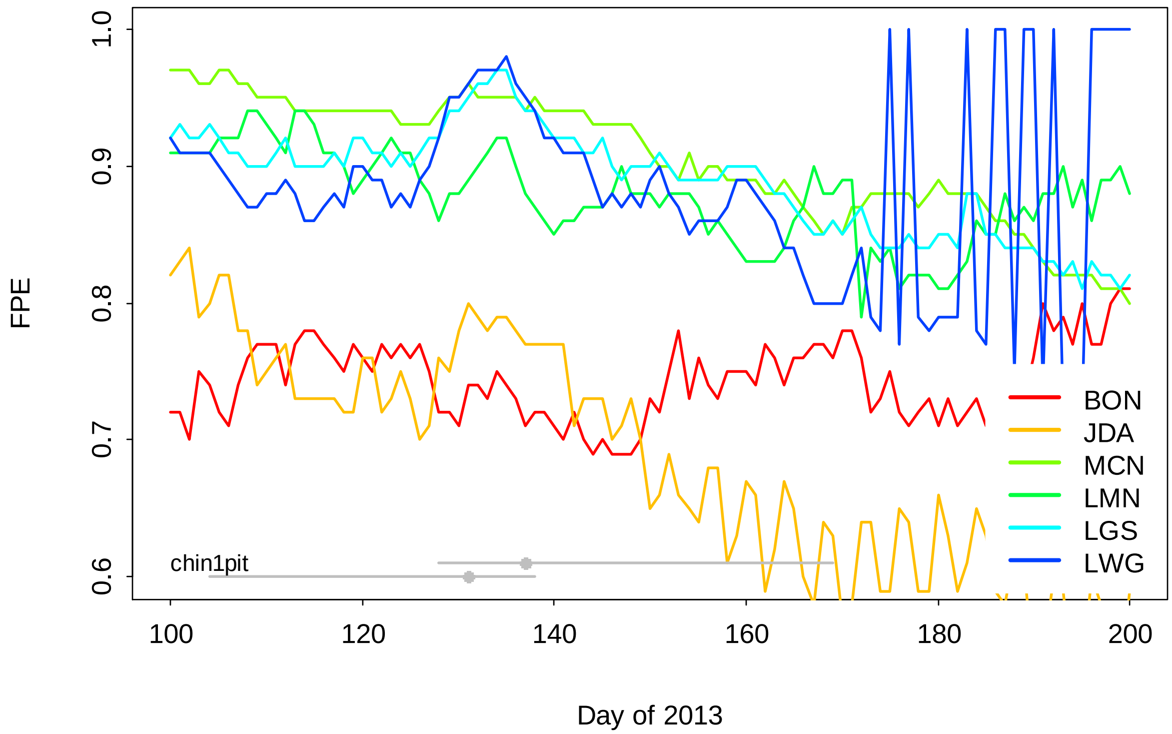


Figure 21 Snake River COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for hatchery Chinook and steelhead. Circles scaled by release count and centered on release day, whiskers show standard error. Blue line shows release-count-weighted survival to date. Final count-weighted average survival written out as well.

Appendix 5: Modeled FPE during migration season



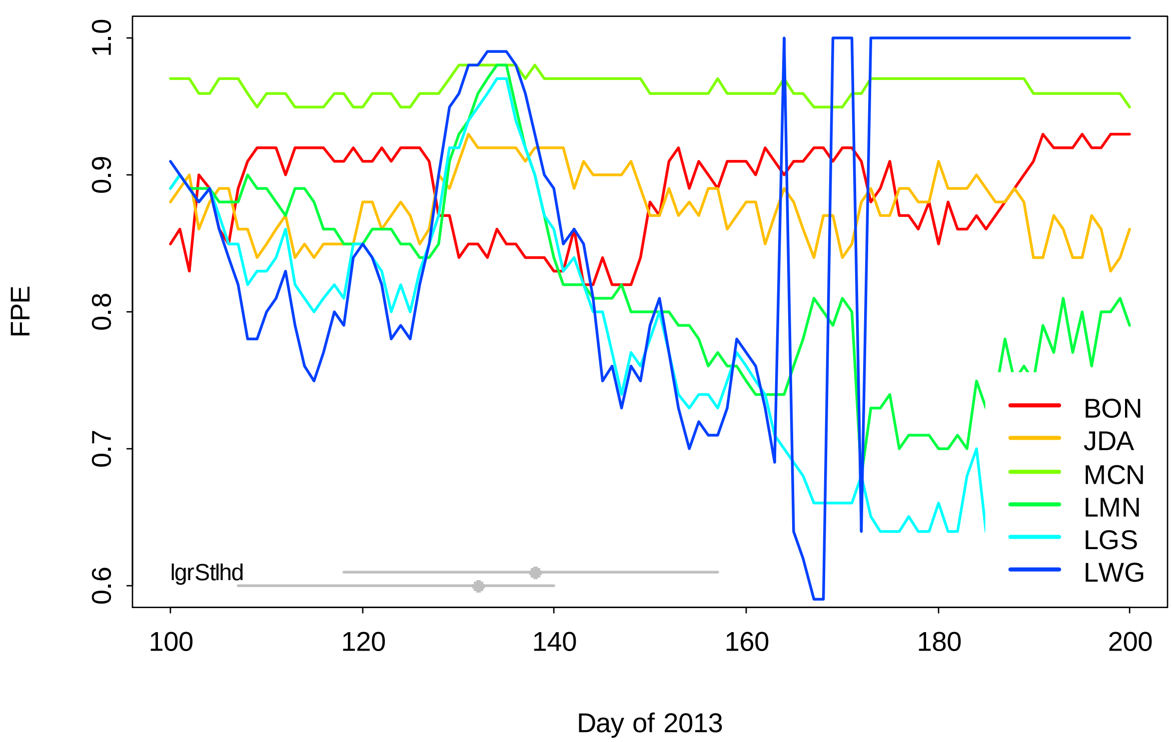


Figure 22 Computed FPE for Chinook and Steelhead in 2013 based on flow, spill, spill efficiency, and FGE in COMPASS runs.

Appendix 5: TDG

Time series at two dams above the Snake and Columbia confluence.